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USACE / NAVFAC / AFCESA / NASA **UFGS-26 41 01.00 10 (November 2008)**

Preparing Activity: USACE **Superseding UFGS-26 41 01.00 10 (April 2006)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2012
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DIVISION 26 - ELECTRICAL

SECTION 26 41 01.00 10

LIGHTNING PROTECTION SYSTEM

11/08

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SECTION 26 41 01.00 10

LIGHTNING PROTECTION SYSTEM
11/08

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NOTE: This guide specification covers the requirements for lightning protection systems for buildings and other structures.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2011; TIA 11-1; Errata 2011; TIA 11-2; TIA 11-3; TIA 11-4) National Electrical Code
NFPA 780	(2011) Standard for the Installation of Lightning Protection Systems

UNDERWRITERS LABORATORIES (UL)

UL 467	(2007) Grounding and Bonding Equipment
UL 96	(2005; Reprint Oct 2010) Standard for Lightning Protection Components
UL 96A	(2007; Reprint Oct 2010) Standard for Installation Requirements for Lightning Protection Systems
UL Electrical Constructn	(2011) Electrical Construction Equipment Directory

1.2 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within

the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings

SD-07 Certificates

Materials

1.3 QUALITY ASSURANCE

Submit detail drawings consisting of a complete list of material, including manufacturer's descriptive and technical literature, catalog cuts, drawings, and installation instructions. Detail drawings shall demonstrate that the system has been coordinated and will function as a unit. Drawings shall show proposed layout and mounting and relationship to other parts of the work.

PART 2 PRODUCTS

2.1 STANDARD PRODUCTS

Provide a system consisting of the standard products of a manufacturer regularly engaged in the production of lightning protection systems and which is the manufacturer's latest UL approved design. The lightning protection system shall conform to NFPA 70 and NFPA 780, UL 96 and UL 96A, except where requirements in excess thereof are specified herein.

2.2 MATERIALS

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NOTE: Designer will list facilities requiring certification of UL inspection. The list is to include all Army facilities used for manufacturing, processing, handling or storing explosives, ammunition or explosive ingredients. On all other Army facilities and on Air Force facilities, this

requirement will be deleted unless specifically requested by the facility user.

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Submit proof of compliance with requirements of UL, where material or equipment is specified to comply. The label of or listing in UL Electrical Constructn will be acceptable evidence. In lieu of the label or listing, a written certificate from an approved nationally recognized testing organization equipped to perform such services, stating that the items have been tested and conform to the requirements and testing methods of Underwriters Laboratories may be submitted.

2.2.1 General Requirements

Do not use any combination of materials that form an electrolytic couple of such nature that corrosion is accelerated in the presence of moisture, unless moisture is permanently excluded from the junction of such metals. Where unusual conditions exist, which would cause corrosion of conductors, use conductors with protective coatings or oversize conductors. Where a mechanical hazard is involved, increase the conductor size to compensate for the hazard or protect the conductors by covering them with molding or tubing made of wood or nonmagnetic material. When metallic conduit or tubing is used, the conductor shall be electrically connected at the upper and lower ends.

2.2.2 Main and Secondary Conductors

Conductors shall be in accordance with NFPA 780 and UL 96 for Class I, Class II, or Class II modified materials as applicable.

2.2.2.1 Copper

Copper conductors used on nonmetallic stacks shall weigh not less than 170 kg/300 m 375 pounds/thousand feet, and the size of any wire in the cable shall be not less than No. 15 AWG. The thickness of any web or ribbon used on stacks shall be not less than No. 12 AWG. Counterpoise shall be copper conductors not smaller than No. 1/0 AWG.

2.2.2.2 Aluminum

Aluminum shall not contact the earth nor shall it be used in any other manner that will contribute to rapid deterioration of the metal. Appropriate precautions shall be observed at connections with dissimilar metals. Aluminum conductors for bonding and interconnecting metallic bodies to the main cable shall be at least equivalent to strength and cross-sectional area of a No. 4 AWG aluminum wire. When perforated strips are provided, strips that are much wider than solid strips shall be. A strip width that is at least twice that of the diameter of the perforations shall be used. Aluminum strip for connecting exposed water pipes shall be not less than No. 12 AWG in thickness and at least 38.1 mm 1-1/2 inch wide.

2.2.3 Air Terminals

Terminals shall be in accordance with UL 96 and NFPA 780. The tip of air terminals on buildings used for manufacturing, processing, handling, or storing explosives, ammunition, or explosive ingredients shall be a minimum of 600 mm 2 feet above the ridge parapet, ventilator or perimeter. On open or hooded vents emitting explosive dusts or vapors under natural or forced draft, air terminals shall be a minimum of 1.5 m 5 feet above the opening.

On open stacks emitting explosive dusts, gases, or vapor under forced draft, air terminals shall extend a minimum of 4.5 m 15 feet above vent opening. Air terminals more than 600 mm 24 inch in length shall be supported by a suitable brace, with guides not less than one-half the height of the terminal.

2.2.4 Ground Rods

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NOTE: Designer will determine type and number of ground rods to be used; based on local conditions, earth resistivity data, and on the size and type of the electrical installation. Copper clad steel rods will be specified for normal conditions. Galvanized coated steel or stainless steel rods will be used where low soil resistivities are encountered and galvanic corrosion may occur between adjacent underground metallic masses and the copper-clad rods. Stainless steel rods have a longer life than the zinc coated steel, but use must be justified based on the higher cost. In high resistivity soils, 3.048 m (10 foot) sectional rods may be used to obtain the required resistance to ground; however where rock is encountered, additional rods, a counterpoise, or ground grid may be necessary. Coordinate and standardize rod selection for individual facilities with other specification sections.
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Rods made of [copper-clad steel] [stainless steel] [solid copper] shall conform to UL 467 and galvanized ferrous rods shall conform to IEEE C135.30. Ground rods shall be not less than19 mm 3/4 inch in diameter and 3.048 m 10 feet in length. Ground rods of copper-clad steel, stainless steel, galvanized ferrous, and solid copper shall not be mixed on the job.

2.2.5 Connectors

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NOTE: The bracketed area in this paragraph is only required on Air Force projects which have a facility which manufactures. processes, handles or stores explosives, ammunition or explosive ingredients.
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Clamp-type connectors for splicing conductors shall conform to UL 96, class as applicable, and, Class 2, style and size as required for the installation. [Clamp-type connectors shall only be used for the connection of the roof conductor to the air terminal and to the guttering. All other connections, bonds, and splices shall be done by exothermic welds or by high compression fittings. The exothermic welds and high compression fittings shall be listed for the purpose. The high compression fittings shall be the type which require a hydraulically operated mechanism to apply a minimum of 10,000 psi.]

2.2.6 Lightning Protection Components

Lightning protection components, such as bonding plates, air terminal supports, chimney bands, clips, and fasteners shall conform to UL 96,

classes as applicable.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify all dimensions in the field, and advise the Contracting Officer of any discrepancy before performing the work. No departures shall be made without the prior approval of the Contracting Officer.

3.2 INTEGRAL SYSTEM

3.2.1 General Requirements

Provide a lightning protection system consisting of air terminals, roof conductors, down conductors, ground connections, and grounds, electrically interconnected to form the shortest distance to ground. All conductors on the structures shall be exposed except where conductors are in protective sleeves exposed on the outside walls. Secondary conductors shall interconnect with grounded metallic parts within the building. Interconnections made within side-flash distances shall be at or above the level of the grounded metallic parts.

3.2.1.1 Air Terminals

Air terminal design and support shall be in accordance with NFPA 780. Terminals shall be rigidly connected to, and made electrically continuous with, roof conductors by means of pressure connectors or crimped joints of T-shaped malleable metal and connected to the air terminal by a dowel or threaded fitting. Air terminals at the ends of the structure shall be set not more than 600 mm 2 feet from the ends of the ridge or edges and corners of roofs. Spacing of air terminals 600 mm 2 feet in height on ridges, parapets, and around the perimeter of buildings with flat roofs shall not exceed 7.5 m 25 feet. In specific instances where it is necessary to exceed this spacing, the specified height of air terminals shall be increased not less than 50 mm 2 inch for each 300 mm foot of increase over 7.5 m 25 feet. On large, flat or gently sloping roofs, as defined in NFPA 780, air terminals shall be placed at points of the intersection of imaginary lines dividing the surface into rectangles having sides not exceeding 15 m 50 feet in length. Air terminals shall be secured against overturning either by attachment to the object to be protected or by means of a substantial tripod or other braces permanently and rigidly attached to the building or structure. Metal projections and metal parts of buildings, smokestacks, and other metal objects that do not contain hazardous materials and that may be struck but not appreciably damaged by lightning, need not be provided with air terminals. However, these metal objects shall be bonded to the lightning conductor through a metal conductor of the same unit weight per length as the main conductor. [Where metal ventilators are installed, air terminals shall be mounted thereon, where practicable. Any air terminal erected by necessity adjacent to a metal ventilator shall be bonded to the ventilator near the top and bottom.] Where metal ventilators are installed with air terminals mounted thereon, the air terminal shall not be more than 610 mm 24 inch away from the farther edge or corner. If the air terminal is farther than this distance, an additional air terminal shall be added in order to meet this requirement. Where metal ventilators are installed with air terminals mounted adjacent, the air terminal shall not be more than 610 mm 24 inches away from the farther edge or corner. If the air terminal is farther than

this distance, an additional air terminal shall be added in order to meet this requirement.

3.2.1.2 Roof Conductors

Roof conductors shall be connected directly to the roof or ridge roll. Sharp bends or turns in conductors shall be avoided. Necessary turns shall have a radius of not less than 200 mm 8 inch. Conductors shall preserve a downward or horizontal course and shall be rigidly fastened every 900 mm 3 feet along the roof and down the building to ground. Metal ventilators shall be rigidly connected to the roof conductor at three places. All connections shall be electrically continuous. Roof conductors shall be coursed along the contours of flat roofs, ridges, parapets, and edges; and where necessary, over flat surfaces, in such a way as to join each air terminal to all the rest. Roof conductors surrounding tank tops, decks, flat surfaces, and flat roofs shall be connected to form a closed loop.

3.2.1.3 Down Conductors

Down conductors shall be electrically continuous from air terminals and roof conductors to grounding electrodes. Down conductors shall be coursed over extreme outer portions of the building, such as corners, with consideration given to the location of ground connections and air terminals. Each building or structure shall have not less than two down conductors located as widely separated as practicable, at diagonally opposite corners. On rectangular structures having gable, hip, or gambrel roofs more than 35 m 110 feet long, there shall be at least one additional down conductor for each additional 15 m 50 feet of length or fraction thereof. On rectangular structures having French, flat, or sawtooth roofs exceeding 75 m 250 feet in perimeter, there shall be at least one additional down conductor for each 30 m 100 feet of perimeter or fraction thereof. On an L- or T-shaped structure, there shall be at least one additional down conductor; on an H-shaped structure, at least two additional down conductors; and on a wing-built structure, at least one additional down conductor for each wing. On irregularly shaped structures, the total number of down conductors shall be sufficient to make the average distance between them along the perimeter not greater than 30 m 100 feet. On structures exceeding 15 m 50 feet in height, there shall be at least one additional down conductor for each additional 18 m 60 feet of height or fraction thereof, except that this application shall not cause down conductors to be placed about the perimeter of the structure at intervals of less than 15 m 50 feet. Additional down conductors shall be installed when necessary to avoid "dead ends" or branch conductors ending at air terminals, except where the air terminal is on a roof below the main protected level and the "dead end" or branch conductor is less than 5 m 16 feet in length and maintains a horizontal or downward coursing. Down conductors shall be equally and symmetrically spaced about the perimeter of the structure. [Down conductors shall be protected by placing in [pvc] [rigid steel] conduit for a minimum distance of 1800 mm 72 inch above finished grade level.] [If the conduit is metal, the down conductor shall be bonded at the top and bottom of the conduit.].

3.2.1.4 Interconnection of Metallic Parts

Metal doors, windows, and gutters shall be connected directly to the grounds or down conductors using not smaller than No. 6 copper conductor, or equivalent. Conductors placed where there is probability of unusual wear, mechanical injury, or corrosion shall be of greater electrical capacity than would normally be used, or shall be protected. The ground

connection to metal doors and windows shall be by means of mechanical ties under pressure, or equivalent.

3.2.1.5 Ground Connections

Ground connections comprising continuations of down conductors from the structure to the grounding electrode shall securely connect the down conductor and ground in a manner to ensure electrical continuity between the two. All connections shall be of the clamp type. There shall be a ground connection for each down conductor. Metal water pipes and other large underground metallic objects shall be bonded together with all grounding mediums. Ground connections shall be protected from mechanical injury. In making ground connections, advantage shall be taken of all permanently moist places where practicable, although such places shall be avoided if the area is wet with waste water that contains chemical substances, especially those corrosive to metal.

3.2.1.6 Grounding Electrodes

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NOTE: Where soil conditions indicate definitely that a counterpoise will not be required, all references to counterpoise should be deleted from the specifications. Using the soil resistance calculate the resistance of the ground rods. When these calculations indicate a combination of two ground rods will exceed 50 ohms or the system ground resistance will exceed [_____] ohms, provide a counterpoise.

For Air Force projects the words in the fourth sentence, "if a counterpoise is not used" should be deleted.

Ten ohms should be used for all installations covered by DARCOM-R 385-100, Safety Manual. Twenty-five ohms is acceptable at most other installations.

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A grounding electrode shall be provided for each down conductor located as shown. A driven ground shall extend into the earth for a distance of not less than 3.0 m 10 feet. Ground rods shall be set not less than 900 mm 3 feet, nor more than 2.5 m 8 feet, from the structures foundation. The complete installation shall have a total resistance to ground of not more than [_____] ohms if a counterpoise is not used. Ground rods shall be tested individually prior to connection to the system and the system as a whole shall be tested not less than [24] [48] hours after rainfall. When the resistance of the complete installation exceeds the specified value or two ground rods individually exceed [_____] ohms, the Contracting Officer shall be notified immediately. A counterpoise, where required, shall be of No. 1/0 copper cable or equivalent material having suitable resistance to corrosion and shall be laid around the perimeter of the structure in a trench not less than 600 mm 2 feet deep at a distance not less than 900 mm 3 feet nor more than 2.5 m 8 feet from the nearest point of the structure. All connections between ground connectors and grounds or counterpoise, and between counterpoise and grounds shall be electrically continuous. Where so indicated on the drawings, an alternate method for grounding electrodes in shallow soil shall be provided by digging trenches radially from the

building. The lower ends of the down conductors [or their equivalent in the form of metal strips or wires] are then buried in the trenches.

3.2.2 Metal Roofs

Wood-Frame, Wall-Bearing Masonry or Tile Structure with Metallic Roof and Nonmetallic Exterior Walls, or Reinforced Concrete Building with Metallic Roof: Metal roofs which are in the form of sections insulated from each other shall be made electrically continuous by bonding. Air terminals shall be connected to, and made electrically continuous with, the metal roof as well as the roof conductors and down conductors. Ridge cables and roof conductors shall be bonded to the roof at the upper and lower edges of the roof and at intervals not to exceed 30 m 100 feet. The down conductors shall be bonded to roof conductors and to the lower edge of the metal roof. Where the metal of the roof is in small sections, the air terminals and down conductors shall have connections made to at least four of the sections. All connections shall have electrical continuity and have a surface contact of at least 1935 square mm 3 square inch.

3.2.3 Metal Roofs With Metal Walls

Wood-Frame Building With Metal Roof and Metal Exterior Walls: The metal roof and the metal walls shall be bonded and made electrically continuous and considered as one unit. The air terminals shall be connected to and made electrically continuous with the metal roof as well as the roof and down conductors. All connections shall have electrical continuity and have a surface contact of at least 1935 square mm 3 square inch.

3.2.4 Steel Frame Building

The steel framework shall be made electrically continuous. Electrical continuity may be provided by bolting, riveting, or welding steel frame, unless a specific method is noted on the drawings. The air terminals shall be connected to the structural steel framework at the ridge. Short runs of conductors shall be used as necessary to join air terminals to the metal framework so that proper placing of air terminals is maintained. Separate down conductors from air terminals to ground connections are not required. Where a grounded metal pipe water system enters the building, the structural steel framework and the water system shall be connected at the point of entrance by a ground connector. Connections to pipes shall be by means of ground clamps with lugs. Connections to structural framework shall be by means of nut and bolt or welding. All connections between columns and ground connections shall be made at the bottom of the steel columns. Ground connections to grounding electrons or counterpoise shall be run from not less than one-half of all the columns distributed equally around the perimeter of the structure at intervals averaging not more than 18 m 60 feet.

3.2.5 Ramps

Lightning protection for covered ramps (connecting passageways) shall conform to the requirements for lightning protection systems for buildings of similar construction. A down conductor and a driven ground shall be placed at one of the corners where the ramp connects to each building or structure. This down conductor and driven ground shall be connected to the counterpoise or nearest ground connection of the building or structure. Where buildings or structures and connecting ramps are clad with metal, the metal of the buildings or structures and metal of the ramp shall be connected to ensure electrical continuity, in order to avoid the

possibility of a flash-over or spark due to a difference in potential.

3.2.6 Igloo-Type Magazines

In earth-covered reinforced-concrete, igloo-type magazines, the reinforcing steel shall be made electrically continuous. Electrical continuity may be provided by clipping or brazing, unless a specific method is noted on the drawings. The air terminals and roof conductors shall be securely connected to, and made electrically continuous with, the reinforcing steel. One air terminal shall be located on the top of the front wall and one on or adjacent to the ventilator in the rear. The air terminals shall extend vertically at least 600 mm 2 feet above the top of the front wall and the highest point on the ventilator. Down conductors and grounding electrodes shall be provided at diagonally opposite corners of the magazine and shall be connected together. Grounding electrodes shall be connected to the horizontal reinforcing rods below the floor line of the wall system. The steel door frame shall be made electrically continuous with the reinforcing steel. The steel door shall be connected to the steel frame by means of a flexible copper strap or cable unless the steel hinges make the door and frame electrically continuous.

3.2.7 Tanks and Towers

3.2.7.1 Wooden Tanks and Towers

The lightning protection system shall consist of air terminals, ridge cables, down conductors, ground connections, and grounds, electrically interconnected to form the shortest distance to ground. Where the roof of the structure ends in a peak, a single air terminal not less than 600 mm 2 feet high will be regarded as sufficient. When the structure does not end in a peak, air terminals not less than 600 mm 2 feet high shall be provided at intervals not exceeding 7.5 m 25 feet along the perimeter of the structure. When the tank or tower is an adjunct of a building, near or touching the perimeter, one of the down conductors shall be extended directly to a ground connection and the other shall be connected to the lightning protection system of the building. When tank or tower is set well within the perimeter of a building, both down conductors shall be connected to the lightning protection system of the building. When the height of the facility exceeds 18 m 60 feet, the down conductors shall be cross-connected at intermediate levels not exceeding 18 m 60 feet. Where buried metal pipes enter the tank or tower, one down connector shall be connected to the pipes, approximately 300 mm 1 foot below grade. Metal guy wires or cables attached to steel anchor rods set in earth will be considered as grounded. Metal guy wires or cables set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.2.7.2 Metal or Reinforced-Concrete Tanks and Towers

The metal or reinforcing steel shall be made electrically continuous. Electrical continuity may be provided by bolting, riveting, or welding metal and tying or clipping reinforcing bars, unless a specific method is noted on the drawings. Air terminals and down conductors are required except on bolted, riveted, or welded 4.8 mm 3/16-inch minimum, steel plate tanks. Ground connections and grounding electrodes are not required on metal tanks that are electrically continuous with a metallic underground pipe system. On other structures, two ground connections shall be provided approximately 180 degrees apart, at the base of the structure. Where buried metal pipes enter the tank or tower, one ground connection shall be

connected to them, approximately 300 mm 1 foot below finished grade. Metal guy wires on tanks and towers shall be grounded. Metal guy wires or cables attached to steel anchor rods set in earth will be considered as grounded. Metal guy wires or cables set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.2.8 Stacks

Metal guy wires for stacks shall be grounded. Metal guy wires or cables attached to steel anchor rods set in the earth will be considered as sufficiently well grounded. Metal guy wires or cables attached to anchor rods set in concrete or attached to buildings or nonconducting supports shall be grounded to a ground rod driven full length into the ground.

3.2.8.1 Metal Stacks

Metal smokestacks shall be electrically continuous and be grounded. Where the construction of the foundation does not provide [_____] ohms maximum to ground, the stack shall be grounded to two ground rods driven full length into the earth. Ground rods shall be located approximately 180 degrees apart and shall be set not less than 900 mm 3 feet from the nearest point of the stack foundation.

3.2.8.2 Nonmetallic Stacks

On nonmetallic smokestacks constructed of brick, hollow tile, or concrete, the air terminals shall be made of solid copper, copper alloy, stainless steel or Monel metal. Air terminals shall be uniformly distributed about the rim of the stack at intervals not exceeding 2.5 m 8 feet and shall extend 450 to 750 mm 18 to 30 inch above the stack if side mounted or 450 mm 18 inch above the stack if top mounted. Air terminals shall be at least 18 mm 5/8 inch in diameter, exclusive of the corrosion protection. Top-mounted air terminals shall not extend more than 450 mm 18 inch above the top of the stack. The air terminals shall be electrically connected together by means of a metal band or ring to form a closed loop about 600 mm 2 feet below the top of the stack. Where the stack has a metal crown, the air terminals shall be connected thereto. Where stacks have a metal lining extending part way up, the lining shall be connected to the air terminal at its upper end and grounded at the bottom. At least two down conductors shall be provided on opposite sides of the stack leading from the ring or crown at the top to the ground. When the stack is an adjunct of a building near or touching the building perimeter, one of the down conductors shall be extended directly to a ground connection while the other may be connected to a lightning protection system on the building. On stacks exceeding 50 m 160 feet in height, the down conductors shall be cross-connected approximately midway between the top and the bottom. Joints in conductors shall be as few as practicable and shall provide a strength in tension equal to that of the conductor. Fasteners of copper or copper-bronze alloy shall be spaced not over 900 mm 3 feet apart for vertical conductors and not over 600 mm 2 feet apart for horizontal conductors. To prevent corrosion by gases, copper air terminals, conductors, and fasteners within 8 m 25 feet of the top of the stack shall have a continuous covering of lead at least 1.6 mm 1/16-inch thick. Stacks partly or wholly of reinforced concrete shall conform to the requirements for nonmetallic stacks, and in addition, the reinforcing steel shall be electrically connected to down conductors at the top and bottom of the concrete.

3.2.9 Post Tensioning Systems

On construction utilizing post tensioning systems to secure precast concrete sections, the post tension rods shall not be used as a path for lightning to ground. Down conductors shall be provided on structures using post tensioning systems; down conductors shall have sufficient separation from post tension rods to prevent side-flashing. Post tension rods shall be bonded to the lightning protection and grounding systems only at the base of the structure; this bonding shall be performed in strict accordance with the recommendations of the post tension rod manufacturer, and shall be done by, or in the presence of, a representative of the manufacturer.

3.3 RAILROADS

Rails that are not electrically continuous and rail switches shall be bonded together by means of flexible copper cable or straps for a distance of at least 30 m 100 feet on each side of structures in which explosives, ammunition, or explosive ingredients are stored, handled, manufactured, or processed. These rails shall also be grounded. Rails shall be grounded at points 45 m 150 feet on each side of overhead line crossings in excess of 600 volts and rails shall be bonded between grounds. At points where the tracks come within 7.5 m 25 feet of structures provided with a grounding system, such grounds shall be interconnected to the nearest rail. The cable used for the interconnection shall be at least 9.5 mm 3/8 inch diameter or the same size as the conductors used on the structure. Isolation joints shall be installed in metal rails outside of hazardous areas to avoid stray currents being conducted into the bonded or grounded area.

3.4 PIERS AND WHARVES

Lightning protection systems for piers and wharves shall conform to the requirements specified for the type of construction involved.

3.5 INTERCONNECTION OF METAL BODIES

Metal bodies of conductance shall be protected if not within the zone of protection of an air terminal. Metal bodies of conductance having an area of 0.258 square m 400 square inch or greater or a volume of 0.0164 cubic m 1000 cubic inch or greater shall be bonded to the lightning protection system using main size conductors and a bonding plate having a surface contact area of not less than 1935.5 square mm 3 square inch. Provisions shall be made to guard against the corrosive effect of bonding dissimilar metals. Metal bodies of inductance shall be bonded at their closest point to the lightning protection system using secondary bonding conductors and fittings. A metal body that exceeds 1.5 m 5 feet in any dimension, that is situated wholly within a building, and that does not at any point come within 1.8 m 6 feet of a lightning conductor or metal connected thereto shall be independently grounded.

3.6 FENCES

Except as indicated below, metal fences that are electrically continuous with metal posts extending at least 600 mm 2 feet into the ground require no additional grounding. Other fences shall be grounded on each side of every gate. Fences shall be grounded by means of ground rods every 300 to 450 m 1000 to 1500 feet of length when fences are located in isolated places, and every 150 to 225 m 500 to 750 feet when in proximity (30 m 100 feet or less) to public roads, highways, and buildings. [Where the fence

consists of wooden posts and horizontal metal strands only, down conductors consisting of No. 8 copper wire or equivalent shall be run from the ground rod the full height of the fence and fastened to each wire, so as to be electrically continuous.] The connection to ground shall be made from the post where it is of metal and is electrically continuous with the fencing. All metal fences shall be grounded at or near points crossed by overhead lines in excess of 600 volts and at distances not exceeding 45 m 150 feet on each side of line crossings.

3.7 EXTERIOR OVERHEAD PIPE LINES

Overhead pipes, conduits, and cable tray that enter a building containing explosives shall be properly grounded on the exterior of the building, preferably to the building grounds at points where the pipes enter the building. Where a separate ground is used, the pipes shall also be bonded to the building ground at points where the pipes are closest to the ground connections. In addition, the pipes shall be bonded to any metallic masses that are within 1.8 m 6 feet of the pipes.

3.8 SEPARATELY MOUNTED SHIELDING SYSTEM, MAST-TYPE

The mast-type protection shall consist of a pole, which, when of a nonconducting material, shall be provided with an air terminal mounted to the top, extending not less than 600 mm 2 feet nor more than 1.5 m 5 feet above the top of the pole and a down conductor run down the side of the pole and connected to the ground rod. When a metal pole is used, the pole will act as a down conductor, and an air terminal need not be provided. Where the resistance of the pole to ground is [_____] ohms or less, additional grounding is unnecessary. Where the resistance exceeds [_____] ohms, additional grounding shall be provided, and the ground connection shall be fastened to the metal pole and the ground. When a ground rod is necessary, the rod shall be driven approximately 1.8 m 6 feet from the base of the pole. When the combined measured resistance to ground of the pole and ground rod exceeds [_____] ohms, the Contracting Officer shall be notified immediately. The grounding system at the base of the pole shall be interconnected with any grounding system provided for the protected structure.

3.9 SEPARATELY MOUNTED SHIELDING SYSTEM, OVERHEAD GROUND-WIRE TYPE

This type of protection shall consist of two or more poles electrically connected to each other by overhead conductors. Where the poles are made of a nonconducting material, an air terminal shall be mounted to the top of each pole and shall extend not less than 600 mm 2 feet nor more than 1.5 m 5 feet above the top of the pole. Down conductors shall be run down the side of the pole, or a guy wire may be used as a conductor. When the guy wire is used, the guy wire and the overhead ground wire shall be dead-ended at the pole. The overhead ground wire and the guy wire shall then be connected to each other by a separate cable using standard cable clamps in such manner that the discharge will not be reversed at any point. Guy wires used as down conductors shall be grounded by means of separate ground rods with cable connections clamped to the lower end of guy wire. Resistance to ground shall not exceed [_____] ohms. Where metal poles are used, air terminals are not required and if resistance of the poles to ground is [_____] ohms or less, additional grounding is unnecessary. Where the resistance to ground exceeds [_____] ohms, additional grounding shall be provided and the ground connection shall be fastened to the metal pole and the ground. The height of the poles shall be sufficient to provide a clearance of not less than 1.8 m 6 feet between the overhead ground wire

and the highest projection of the building. When the ground cable runs across and is used to protect stacks or vents that emit explosive dusts, vapors, or gases under forced draft, the cable shall have at least 4.5 m 15 feet clearance above the stack or vent. When grounding is required, a ground rod shall be driven approximately 1.8 m 6 feet from the base of each pole. When the combined measured resistance to ground of the pole and ground rod exceeds [_____] ohms, the Contracting Officer shall be notified immediately. When a counterpoise is used, the entire system resistance requirement of [_____] ohms or less need not be met.

3.10 INSPECTION

The lightning protection system will be inspected by the Contracting Officer to determine conformance with the requirements of this specification. No part of the system shall be concealed until so authorized by the Contracting Officer.

-- End of Section --