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DIVISION 26 - ELECTRICAL

SECTION 26 41 00.00 40

LIGHTNING PROTECTION SYSTEM

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PART 1 GENERAL

1.1 REFERENCES

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.

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.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

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

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE Std 81 (1983) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Part 1) Normal Measurements

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2008; AMD 1 2008) National Electrical Code - 2008 Edition

NFPA 780 (2007) Standard for the Installation of Lightning Protection Systems

U.S. GENERAL SERVICES ADMINISTRATION (GSA)

FS A-A-52913 Splice Connectors

UNDERWRITERS LABORATORIES (UL)

UL 467 (2007) Standard for Grounding and Bonding Equipment

UL 96 (2005) Standard for Lightning Protection

Components

UL 96A

(2007) Standard for Installation
Requirements for Lightning Protection
Systems

UL Electrical Constructn

(2009) Electrical Construction Equipment
Directory

1.2 RELATED REQUIREMENTS

Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS applies to this section with additions and modifications specified herein.

1.2.1 Verification of Dimensions

Contractor shall become familiar with all details of work, verify all dimensions in field, and shall advise Contracting Officer of any discrepancy before performing work. Make no departures without prior approval of Contracting Officer.

1.2.2 System Requirements

Materials shall consist of standard products of a manufacturer regularly engaged in production of lightning protection systems and manufacturer's latest UL approved design. Lightning protection system and materials shall conform to NFPA 70, NFPA 780, UL 96 and UL 96A.

1.3 SUBMITTALS

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. Keep submittals to the minimum required for adequate quality control.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" 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.

Government approval is required for submittals with a "G" designation;
submittals not having a "G" designation are [for Contractor Quality Control
approval.][for 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:

NOTE: Modify submittals paragraphs to ensure that
an appropriate submittal is required for each item
in the project.

SD-02 Shop Drawings

Overall lightning protection system[; G][; G, [_____]]

Each major component[; G][; G, [_____]]

SD-03 Product Data

Submit manufacturer's catalog data for the following items:

Air Terminals

Main and Secondary Conductors

Ground Rods

Clamp-Type Connectors

Lightning Protection Components

Hardware

Accessories

SD-06 Test Reports

Grounding system test[; G][; G, [_____]]

Lightning protection system inspection[; G][; G, [_____]]

SD-07 Certificates

UL listing or label[; G][; G, [_____]]

Submit Certificates in accordance with paragraph entitled, "System
Ratings," of this section.

1.4 QUALITY ASSURANCE

In each standard referred to herein, consider the advisory provisions to be
mandatory, as though the word "shall" has been substituted for "should"
wherever it appears. Interpret references in these standards to "authority

having jurisdiction," or words of similar meaning, to mean Contracting Officer.

1.4.1 Installation Drawings

- a. Submit installation shop drawing for the [overall lightning protection system](#). Drawings shall include physical layout of the equipment, dimensions, mounting details, relationship to other parts of the work, and wiring diagram.
- b. Submit detail drawings for [each major component](#) to include manufacturer's descriptive and technical literature, catalog cuts, and installation instructions.

1.4.2 UL Listing or Label

Submit proof of compliance. Label of or listing in [UL Electrical Constructn](#) is acceptable evidence. In lieu of label or listing, submit written certificate from an approved, nationally recognized testing organization equipped to perform such services, stating that items have been tested and conform to requirements and testing methods of Underwriters Laboratories.

1.5 SITE CONDITIONS

Contractor will become familiar with details of the work, verify dimensions in the field, and advise Contracting Officer of discrepancies before performing work. Deviations from contract drawings will not be made without prior approval of Contracting Officer.

PART 2 PRODUCTS

2.1 MATERIALS

Do not use a combination of materials that forms an electrolytic couple of such nature that corrosion is accelerated in presence of moisture unless moisture is permanently excluded from the junction of such metals. Where unusual conditions exist which would cause corrosion of conductors, provide conductors with protective[[tinned](#)] coatings. Where a mechanical hazard is involved, or protect conductors by covering them with molding or tubing made of wood or nonmagnetic material. When metallic conduit or tubing is provided, electrically bond conductor to conduit or tubing at the upper and lower ends by clamp type connectors or welds (including exothermic).

Lightning protection equipment, [Accessories](#), and [Hardware](#) shall conform to [NFPA 70](#), [NFPA 780](#), and [UL 96](#).

2.1.1 Main and Bonding Conductors

[NFPA 780](#) and [UL 96](#) Class I, Class II, or Class II modified materials as applicable.

Size of conductors shall not be less than specified in [NFPA 780](#).

2.1.2 Copper

For Class I materials (structures not exceeding [75 ft](#) in height), provide copper main conductors that do not weigh less than [\[187\]\[_____\]](#) [pounds per thousand feet](#), have a cross section area of not less than [\[57,400\]\[_____\]](#) [circular mils](#) and minimum strand size of not less than [\[17\]\[_____\]](#) AWG.

For Class II materials (structures exceeding 75 ft in height), provide copper main conductors that do not weigh less than [375][_____] pounds per thousand feet, have a cross section area of not less than [115,000][_____] circular mils and minimum strand size of not less than [15][_____] AWG. Provide loop conductors that are comprised of copper conductors not smaller than No. [1/0][_____] AWG.

2.1.3 Aluminum

NOTE: This paragraph is to be deleted when used for
Atlantic Division, Naval Facilities Engineering
Command. Exception, Aluminum conductors are
allowable in Atlantic Division when specifically
required by the NFPA 780 (e.g. aluminum structures,
etc.)

For Class I materials (structures not exceeding 75 ft in height), provide aluminum main conductors that do not weigh less than [95][_____] pounds per thousand feet, have a cross section area of not less than [98,600][_____] circular mils and minimum strand size of not less than [14][_____] AWG. For Class II materials (structures exceeding 75 ft in height), provide aluminum main conductors that do not weigh less than [190][_____] pounds per thousand feet, have a cross section area of not less than [192,000][_____] circular mils and minimum strand size of not less than [13][_____] AWG.

Do not allow aluminum to contact the earth and do not use in any other manner that will contribute to rapid deterioration of the metal. Observe appropriate precautions at connections with dissimilar metals in accordance with NFPA 70 Article 110-14. Provide aluminum cable conductors for bonding and interconnecting metallic bodies to main cable that are at least equivalent to strength cross-sectional area of a No. 4 AWG aluminum wire.

2.2 COMPONENTS

2.2.1 Air Terminals

Provide terminals in accordance with UL 96, except provide Class II for Class I and Class II applications. Support air terminals more than 610 mm 24 inches in length by suitable brace, with guides, not less than one-half the height of the terminal.

Air terminals shall be [16 millimeter 5/8-inch aluminum][15 millimeter 1/2-inch diameter nickel-tipped copper] with length and location as indicated. Fasten air terminals to a [bronze][aluminum] connector with a male threaded stud on which the female threaded air-terminal shaft shall be mounted

Air terminals shall be not less than 250 millimeter 10-inches high above the object to protect, tapered to a point. Separate points are not required on top of air terminals, but if used, the points shall be of substantial construction and securely attached by screw or slip joints. Air terminals more than [450] [_____] millimeter 24-inches high shall be supported by a suitable brace with guide(s) not less than one-half the height of the air terminal.

2.2.2 Ground Rods

NOTE: The designer will determine the type and number of ground rods to be used based on local conditions and earth resistivity data. 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 zinc coated steel, but use of these must be justified based on the higher cost. In high resistivity soils, 3050 mm 10 foot sectional rods may be used to obtain the required resistance to ground; however, where rock is encountered, additional rods, a ground loop, or ground grid may be necessary. Coordinate and standardize rod selection for individual facilities with other specification sections.

Provide [ground rods made of [copper-clad steel] [stainless steel] [solid copper] conforming to UL 467.] [galvanized ferrous rods conforming to ANSI C135.30.] Provide ground rods that are not less than 20 mm 3/4 inch in diameter and 3050 mm 10 feet in length. Do not mix ground rods of copper-clad steel, stainless steel, galvanized ferrous, or solid copper on the same job.

2.2.3 Grounding Plates

NOTE: The use of grounding plates is discouraged in Military Handbook MIL-HDBK-1004/6, paragraph 3.3.4; however, the use of grounding plates is an acceptable alternative to ground rods in areas where excessive rock and surface ledge is encountered.

Provide grounding plates made of [copper-clad steel][iron][stainless steel] [solid copper] conforming to UL 96.

2.2.4 Connections and Terminations

Provide connectors for splicing conductors that conform to UL 96, class as applicable. Conductor connections can be made by clamps or welds (including exothermic). Provide style and size connectors required for the installation [of corrosion-resistant material (bimetallic) affording protection against electrolysis when joining dissimilar metals]. [Only use clamp-type connectors 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. List the exothermic welds and high compression fittings 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.]

2.2.5 Connector Fittings

Provide connector fittings for "end-to-end", "Tee", or "Y" splices that conform to NFPA 780.

2.2.6 Lightning Protection Components

Provide bonding plates, air terminal supports, chimney bands, clips, and fasteners that conform to UL 96 classes as applicable.

2.3 MAIN AND SECONDARY CONDUCTORS

**NOTE: Delete all references to a counterpoise when
soil conditions indicate that a counterpoise is not
required.**

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

[Mass Weight of copper conductors shall be not less than 0.283 kilogram per meter 187.5 pounds per thousand feet, and the size of any wire of this cable shall be not less than AWG No. 17. Copper tube or solid-section conductors of copper shall weigh not less than 0.283 kilogram per meter 187.5 pounds per thousand feet, and no tube wall shall be less than AWG No. 20. Thickness of any copper ribbon or strip shall be not less than AWG No. 16. Copper conductors used for counterpoise shall be not smaller than AWG No. 1/0.]

[Do not allow aluminum to contact or touch the earth, dissimilar metals, or constructions where rapid deterioration of the metal could result. Observe precautions at connections with dissimilar metals. Aluminum cable conductors shall be electrical conductor-grade aluminum and weigh not less than 0.14 kilogram per meter 95 pounds per thousand feet. Size of any wire of the cable shall be not less than AWG No. 14. 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 AWG No. 4 aluminum wire. Aluminum strip conductors for interconnecting metallic bodies to the main conductor cable, when void of perforations, shall be not less than No. 14 and at least 15 millimeter 1/2-inch wide. When 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 AWG No. 12 and at least 40 millimeter 1-1/2-inches wide.]

2.4 CLAMP-TYPE CONNECTORS

Clamp connectors for splicing conductors shall conform to UL 96 and FS A-A-52913, Class 2 noninsulated, style and size as required for the installation. Connectors shall be of corrosion-resistant material and shall afford protection against electrolysis.

2.5 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 INTEGRAL SYSTEM

Lightning protection system consists of air terminals, roof conductors, down conductors, ground connections, grounding electrodes and ground loop conductor. Electrically interconnect lightning protection system to form the shortest distance to ground. Do not use nonconducting parts of the structure as part of the building's lightning protection system. Expose conductors on the structures except where conductors are required to be in protective sleeves. Interconnect secondary conductors with grounded metallic parts within the building. Make interconnections within side-flash distances at or above the level of the grounded metallic parts.

3.1.1 Air Terminals

Provide air terminal design and support conforming to NFPA 780. Rigidly connect terminals to, and make electrically continuous with, roof conductors by means of pressure connectors or crimped joints of T-shaped malleable metal. Provide pressure connector or crimped joint with a dowel or threaded fitting to connect ground rod conductor with air terminal. Set air terminals at ends of structures not more than 610 mm 2 feet from ends of ridges and corners of roofs. Do not exceed 7620 mm 25 feet in spacing of 610 mm 2 foot high or greater air terminals on ridges, parapets, and around perimeter of building with flat roofs or 20 feet in spacing of air terminals less than 2 feet high. When necessary to exceed this spacing, use taller air terminals and the rolling sphere method. On large flat, or gently sloping roofs, as defined in NFPA 780, place air terminals at points of the intersection of imaginary lines dividing the surface into rectangles having sides not exceeding 15 m 50 feet in length. Secure air terminals against overturning either by attachment to the object to be protected or by means of a substantial tripod or other braces which are permanently and rigidly attached to the building or structure. Metal projections and metal parts of buildings such as smokestacks and other metal objects that are at least 3/16 inch 4.763 mm thick and that do not contain hazardous materials, need not be provided with air terminals. However, bond these metal objects to a lightning conductor through a metal conductor of the same unit weight per length as the main conductor. [Where metal ventilators are installed, mount air terminals thereon, where practical. Bond air terminals, erected by necessity adjacent to a metal ventilator, to the ventilator near the top and bottom.] [Where nonmetallic spires, steeples, or ventilators are present, mount air terminals to the side. In addition, where spires or steeples project more than 3050 mm 10 feet above the building, continue conductor from air terminal to nearest down conductor securely connect thereto.] [Where metal ventilators are installed, mount air terminals 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, add an additional air terminal 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, add an additional air terminal in order to meet this requirement.]

Air terminal tips on buildings used for manufacturing, processing, handling, or storing explosives, ammunition, or explosive ingredients shall

be a minimum of 600 millimeter 2 feet above the ridge parapet, ventilator or perimeter.

Air terminals shall be a minimum of 1500 millimeter 5 feet above the opening on open or hooded vents emitting explosive dusts or vapors under natural or forced draft.

Air terminals shall extend a minimum of 4500 millimeter 15 feet above vent opening on open stacks emitting explosive dusts, gases, or vapor under forced draft.

3.1.2 Roof Conductors

Connect roof conductors directly to the roof or ridge roll. Avoid sharp bends or turns in conductors. Do not make turns of less than 205 mm 8 inches radius. Preserve horizontal or downward course on conductors. Rigidly fasten conductors every 915 mm 3 feet along the roof and down the building to the ground. Rigidly connect metal ventilators to the roof conductor at [two][three] places. Make connections electrically continuous. Course roof conductors along 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. Connect roof conductors surrounding tank tops, decks, flat surfaces, and flat roofs to form a closed loop.

3.1.3 Down Conductors

Make down conductors electrically continuous from air terminals and roof conductors to grounding electrodes. Course down conductors over outer extreme portions of the building, such as corners, with consideration given to location of ground connections and air terminals. Provide each building or structure not less than two down conductors located as widely separated as practicable, such as at diagonally opposite corners. [Structures exceeding 76 m 250 feet in perimeter, provide at least one additional down conductor for each 30 m 100 feet of perimeter or fraction thereof.] Provide enough conductors so that the average distance between them along the perimeter is not greater than 30 m 100 feet. [Structures exceeding 15 m 50 feet in height, provide at least one additional down conductor for each additional 18 m 60 feet of height or fraction thereof, except that this application will not cause down conductors to be placed about the perimeter of the structure at intervals of less than 15 m 50 feet.] Install additional down conductors 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. Equally and symmetrically spaced down conductors about the perimeter of the structure. Protect conductors where necessary, to prevent physical damage or displacement to the conductor. [Protect down conductors 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, bond the down conductor at the top and bottom of the conduit.].

3.1.4 Interconnection of Metallic Parts

Connect metal doors, windows, and gutters directly to ground or down conductors using not smaller than No. 6 copper conductor, or equivalent. Where there is probability of unusual wear, mechanical injury, or corrosion, provide conductors with greater electrical capacity than normal or protect the conductor. Provide mechanical ties or pressure connectors

between grounds and metal doors and windows.

3.1.5 Ground Connections

Securely connect conductor forming continuations of down conductors from structure to grounding electrode in a manner to ensure electrical continuity between the two. Provide [clamp type connections][welds (including exothermic)] for continuation. Provide a ground connection for each down conductor. Attach down conductors to ground [rods] [plates] by welding (including exothermic), brazing, or clamping. Provide clamps suitable for direct burial. Protect ground connection from mechanical injury. Bond metal water pipes and other large underground metallic objects together with all grounding mediums. In making ground connections, take advantage of all permanently moist places where practicable, although avoid such places when area is wet with waste water that contains chemical substances, especially those corrosive to metal.

3.1.6 Grounding Electrodes

NOTE: Where soil conditions indicate definitely that a ground loop will not be required, all references to a ground loop should be deleted from the specifications.

In accordance with MIL-HDBK-1004/6, the maximum ground resistance for any lighting protection system should not exceed 10 ohms.

Provide grounding electrode for each down conductor. Extend driven ground rods into the existing undisturbed earth for a distance of not less 3050 mm [10][20] feet. Set ground rods not less than 610 mm [2][3] feet nor more than 3050 mm [6][8][10] feet, from the structure. After the completed installation, measure the total resistance to ground using the fall-of-potential method described in IEEE Std 81. Maximum resistance of a driven ground rod shall be [10][25][_____] ohms, under normally dry conditions [when a ground loop is not used]. Use a ground loop when two of any three ground rods, driven not less than 3050 mm 10 feet into the ground, a minimum of 3050 mm 10 feet apart, and equally spaced around the perimeter, give a combined value exceeding 50 ohms immediately after having driven. For ground loop, provide continuous No. [1/0][_____] bare stranded copper cable or equivalent material having suitable resistance to corrosion. Lay ground loop around the perimeter of the structure in a trench not less than 765 mm [18][24][30] inches below grade, at a distance not less than 610 mm [2][3] feet nor more than 3050 mm [6][8][10] feet from the nearest point of the structure. Install a ground loop in earth undisturbed by excavation, not earth fill, and do not locate beneath roof overhang, or wholly under paved areas or roadways where rainfall cannot penetrate to keep soil moist in the vicinity of the cable. Make connections between ground conductors and grounds or ground loop, and between ground loop and grounds electrically continuous.

3.1.7 Grounding Plates

NOTE: The use of grounding plates is discouraged in Military Handbook MIL-HDBK-1004/6, paragraph 3.3.4; however, the use of grounding plates is an

**acceptable alternative to ground rods in areas where
excessive rock and surface ledge is encountered.**

Provide a grounding plate for down conductor. Set grounding plates not less than 610 mm 2 feet nor more than 3050 mm 10 feet, from the structure. Grounding plate is to be buried as deeply in the existing dirt as local conditions allow, without exceeding 3050 mm 10 feet in depth.

3.2 APPLICATIONS

3.2.1 Nonmetallic Exterior Walls with Metallic Roof

Bond metal roof sections together which are insulated from each other so that they are electrically continuous. Connect air terminals so that they are electrically continuous with the metal roof as well as the roof conductors and down conductors. Bond ridge cables and roof conductors to the roof at upper and lower edges of roof and at intervals not to exceed 30 m 100 feet. Bond down conductors to roof conductors and to lower edge of metal roof. Where metal of roof is in small sections, make connections between air terminals and down conductors to at least four sections of the metal roof. Make connections electrically continuous and have a surface contact of at least 1935 square mm 3 square inches.

3.2.2 Metal Roofs with Metal Walls

Bond metal roof and metal walls so that they are electrically continuous and considered as one unit. Connect air terminals to and make them electrically continuous with the metal roof as well as the roof down conductors. Bond all roof conductors and down conductors to metal roof or metal walls at upper and lower edges at intervals not to exceed 30 m 100 feet. Make all connections electrically continuous and have surface contact of at least 1935 square mm 3 square inches.

3.2.3 Steel Frame Building

Make the steel framework of the building electrically continuous. Electrical continuity may be provided by bolting, riveting, or welding unless another specific method is indicated. Connect air terminals to the structural steel framework at the ridge. Provide short runs of conductors 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 water system enters the building, securely connect structural steel framework and water system at point of entrance by a ground connector. Make connections to pipes by means of ground clamps with lugs. Make connections to structural framework by means of nut and bolt or welding. Make connections between columns and ground connections at bottom of steel columns. Make ground connections to grounds or ground loop runs from not less than one-half of the columns distributed equally around perimeter of structure at intervals averaging not more than 60 feet. When no water system enter the structure, run ground connections from steel columns distributed equally around the perimeter of the structure at intervals averaging not more than 60 feet. Bond metal doors, windows, gutters, and similar metal installation to steel work of the building. Provide a grounding electrode for each ground connection.

3.2.4 Ramps and Covered Passageways

[Ramps and covered passageways which are in the zone of protection of a lightning protection system, as defined by NFPA 780, need no additional lightning protection.] Ramps and covered passageways [which are outside the zone of protection of a lightning protection system] shall be provided with lightning protection conforming to the requirements for lightning protection systems for buildings of similar construction. Place a down conductor and a driven ground at the corners where the ramp connects to each building or structure. Connect down conductor and driven ground to the ground loop or nearest ground connection of the building or structure. Where buildings or structures and connecting ramps are clad with metal, connect metal of the buildings or structures and metal of the ramp in a manner to ensure electrical continuity, in order to avoid the possibility of a flash-over or spark due to a difference in potential. Make connections electrically continuous and have a surface contact area of at least 1935 square mm 3 square inches.

3.2.5 Tanks and Towers

3.2.5.1 Wooden Tanks and Towers

Electrically interconnect lightning protection system components (such as: air terminals, ridge cables, down conductors, ground connections, and grounds) to form the shortest distance to ground without passing through any nonconducting parts of the structure. Where the roof of the structure ends in a peak, a single air terminal not less than 610 mm 2 feet high will be regarded as sufficient. When structure does not end in a peak, provide air terminals not less than 610 mm 2 feet high at intervals not exceeding 7620 mm 25 feet along the perimeter of the structure. When the tank or tower is an adjunct of a building, near or touching the perimeter, extend one of the down conductors directly to a ground connection and connect the other to lightning protection of the building. When tank or tower is set well within the perimeter of the building, connect both down conductors to lightning protection system of the building. When height of the structure exceeds 30 m 100 feet, cross-connect down conductors midway between the top and bottom. Where buried metal pipes enter tank or tower, connect one down conductor to pipes, approximately 305 mm 1 foot below grade. Ground metal guy wires or cables set in concrete or attached to buildings or nonconducting supports to a ground rod driven full length into the ground.

3.2.5.2 Metal or Reinforced-Concrete Tanks and Towers

Make metal or reinforcing steel 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 4.75 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, provide two ground connections approximately 3.14 rad 180 degrees apart at the base of the structure. Connect each buried metal pipe entering the tank or tower to one ground connection approximately 305 mm one foot below finished grade. Ground metal guy wires on tanks and towers. Metal guy wires or cables attached to steel anchor rods set in earth will be considered as grounded. Ground metal guy wires or cables set in concrete or attached to buildings or nonconducting supports to a ground rod driven full length into the ground.

3.2.6 Stacks

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

3.2.6.1 Metal Stacks

Make metal smokestacks electrically continuous and to ground. Heavy-duty metal stacks having a metal thickness of 4.75 mm 3/16 inches or greater do not require air terminals or down conductors. Otherwise, provide two [ground rods][grounding plates] driven full length into the earth. Locate [ground rods][grounding plates] approximately 3.14 rad 180 degrees apart and set [ground rods] [grounding plates] not less than 915 mm 3 feet nor more than 2440 mm 8 feet from the nearest point of the stack foundation.

3.2.6.2 Nonmetallic Stacks

On nonmetallic smokestacks constructed of brick, hollow tile, or concrete, make the air terminals solid copper, copper alloy, stainless steel or Monel metal. Distribute uniformly about the rim of the stack at intervals not exceeding 2440 mm 8 feet and extending at least 765 mm 30 inches above the rim of stack. Electrically connect air terminal together by means of a metal band or ring to form a closed loop about 2 feet 610 mm below the top of the stack. Where the stack has a metal crown, connect air terminals to the metal crown. Where stacks have metal lining extending part way up, connect lining to air terminal at its upper end and ground at the bottom. Provide at least two down conductors 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 building near or touching the building perimeter, extend one of the conductors directly to a ground connection while the other may be connected to lightning protection system on the building. On stacks exceeding 48 m 160 feet in height, cross-connect down conductors approximately midway between the top and bottom. Reduce joints in conductors to a minimum and make joints to have the same tension strength as the conductors that are joining. Space fasteners of copper or copper-bronze alloy not over 915 mm 3 feet apart for vertical conductors and not over 610 mm 2 feet apart for horizontal conductors. To prevent gases from corroding copper air terminals, provide conductors and fasteners within 7620 mm 25 feet of the top of stack with continuous coating of hot dipped lead or an equivalent coating. Provide conductors conforming to the requirements for nonmetallic stacks for stacks partly or wholly of reinforced concrete. For nonmetallic stacks, electrically connect reinforcing steel to down conductors at top and bottom of concrete.

3.2.7 IGLOO-TYPE MAGAZINES

Reinforcing steel in earth-covered reinforced-concrete, make igloo-type magazines electrically continuous. Provide electrical continuity by clipping or brazing, unless a specific method is noted on the drawings. Air terminals and roof conductors shall be securely connected to, and made electrically continuous with, the reinforcing steel. Locate one air terminal on the top of the front wall and one on or adjacent to the ventilator in the rear. Air terminals shall extend vertically at least 600 millimeter 2 feet above the top of the front wall and the highest point on the ventilator. Provide down conductors and grounding electrodes at diagonally opposite corners of the magazine and connect together. Connect

grounding electrodes to the horizontal reinforcing rods below the floor line of the wall system. Make steel door frames electrically continuous with the reinforcing steel. Connect steel doors to steel frames by means of a flexible copper strap or cable unless the steel hinges make the door and frame electrically continuous.

3.2.8 Post Tensioning Systems

On construction utilizing post tensioning systems to secure precast concrete sections, do not use the post tension rods as a path for lightning to ground. Provide down conductors on structures using post tensioning systems; down conductors shall have sufficient separation from post tension rods to prevent side-flashing. Bond post tension rods to the lightning protection and grounding systems only at the base of the structure; perform this bonding 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 INTERFACE WITH OTHER STRUCTURES

3.3.1 Interconnection of Metal Bodies

Protect metal bodies of conductance if not within the zone of protection of an air terminal. All metal bodies of conductance having an area of 0.258 square meter 400 square inches or greater or a volume of 0.016 cubic meter 1000 cubic inches 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 1900 square millimeter 3 square inches. 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 1500 millimeter 5 feet in any dimension, that is situated wholly within a building, and that does not at any point come within 1800 millimeter 6 feet of a lightning conductor or metal connected thereto shall be independently grounded.

3.3.2 Fences

Except as specified below, metal fences that are electrically continuous with metal posts extending at least 610 mm 2 feet into the ground require no additional grounding. Ground other fences on each side of every gate at gate posts, at corner posts, and at end posts. Bond gate to adjacent fence post utilizing flexible copper grounding braid with sufficient slack to permit 3.14 rad 180 degree opening of the gate. Provide flexible copper ground braid which has an ampacity equivalent to that of the fence ground wire specified herein. Provide [ground rods][grounding plates] every 305 to 457 m 1000 to 1500 feet for grounding fences when fences are located in isolated places, and every 152 to 228 m 500 to 750 feet when in proximity (30 m 100 feet or less) to public roads, highways, and buildings. Provide connection to ground from the post where it is metal and is electrically continuous with the fencing using removable ground clamps on the fence posts and split-bolt connectors suitable for dissimilar metals on the fence fabric and barbed wire. [Where the fence consists of wooden posts and horizontal metal strands only, run down conductors consisting of No. 8 copper wire or equivalent from the ground rod the full height of the fences and fastened to each wire, so as to be electrically continuous.] Make connections to ground from the horizontal metal strand using split-bolt connectors suitable for dissimilar metals on the fence fabric and barbed wire. Ground metal fences at or near points 45 m 150 feet on each side of medium and high voltage, (meaning in excess of 600 volts,) overhead line

crossings. [Ground metal fences at 45 m 150 foot intervals where high and medium voltage lines are directly overhead and run parallel to the fence.]

3.3.3 Exterior Overhead Pipe Lines

Properly ground overhead pipes, conduits, and cable trays on the exterior of the building that enter a building, preferably to building grounds at points where pipes enter the building. Where a separate ground is provided, bond the pipes to the building ground at points where the pipes are closest to the ground connections. In addition, bond pipes to any metallic masses that are within 1830 mm 6 feet of the pipe.

3.4 SEPARATELY MOUNTED SHIELDING SYSTEM

3.4.1 Mast Type

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 millimeter 2 feet nor more than 1500 millimeter 5 feet above the top pole and a down conductor run down the side of the pole. Where resistance of the metal pole to ground is [_____] ohms or less, additional grounding is unnecessary. Where resistance exceeds [_____] ohms or less, 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, drive the rod approximately 1800 millimeter 6 feet from the base of the pole. When resistance to ground of this rod is more than [_____] ohms, an additional ground rod shall be driven not closer than 3000 millimeter 10 feet to the first rod. When resistance of the system to ground is still greater than [_____] ohms when the two ground rods are connected together, a counterpoise, consisting of approximately 9000 millimeter 30 feet of 25 millimeter No. AWG 1/0 copper cable buried in a trench not less than 600 millimeter 2 feet deep in the form of a circle or square around the base of the pole, shall be provided. When a counterpoise is used, the entire system resistance requirement of [_____] ohms or less need not be met. Grounding system at the base of the pole shall be interconnected with any grounding system provided for the protected structure.

3.4.2 Overhead Ground-Wire Type

Overhead ground-wire 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 millimeter 2 feet nor more than 1500 millimeter 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. Overhead ground wires and the guy wires 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, provide additional grounding and fasten the ground connection to the metal pole and the ground. Height of the poles shall be sufficient to provide a clearance of not less than 1800 millimeter 6 feet from the base

of each pole. When the resistance to ground of this rod is more than [_____] ohms, drive an additional ground rod not closer than 3000 millimeter 10 [_____] feet from the first rod. When the resistance of the entire system to ground is still greater than [_____] ohms, a counterpoise consisting of at least 15 meter 50 feet of AWG No. 1/0 copper cable buried in a trench not less than 600 millimeter 2 feet deep shall be provided. When a counterpoise is used, the entire system resistance requirement of [_____] ohms or less need not be met.

3.5 RESTORATION

Where sod has been removed, place sod as soon as possible after completing the backfilling. Restore to original condition the areas disturbed by trenching, storing of dirt, cable laying, and other work. Include necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging or mulching in any restoration. Maintain disturbed surfaces and replacements until final acceptance.

3.6 FIELD QUALITY CONTROL

3.6.1 Grounding System Test

Test the grounding system to ensure continuity and that resistance to ground is not in excess of [10][25][_____] ohms. Test the ground rod for resistance to ground before making connections to the rod. Tie the grounding system together and test for resistance to ground. Make resistance measurements in dry weather, not earlier than 48 hours after rainfall. Include in the written report: locations of ground rods, resistance, and soil conditions at the time that measurements were made. Submit results of each test to the Contracting Officer.

3.6.2 Lightning Protection System Inspection

Make visual inspections to verify that there are no loose connections which may result in high resistance joints, and that conductors and system components are securely fastened to their mounting surfaces and are protected against accidental mechanical displacement.

3.6.3 SYSTEM RATINGS

Submit certificates showing compliance with UL requirements for "Master Label" ratings.

Lightning-protection systems conforming to the installation requirements of UL 96A shall be qualified for a UL "Master Label" rating. Installed lightning-protection system shall be inspected and approved by a certified UL inspector.

3.7 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 --