

\*\*\*\*\*  
USACE / NAVFAC / AFCEA / NASA            UFGS-26 41 00.00 20 (April 2006)  
-----  
Preparing Activity:    NAVFAC            Replacing without change  
   UFGS-13100N (February 2003)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 18 July 2006

Latest change indicated by CHG tags.

\*\*\*\*\*

### SECTION TABLE OF CONTENTS

#### DIVISION 26 - ELECTRICAL

#### SECTION 26 41 00.00 20

#### LIGHTNING PROTECTION SYSTEM

04/06

#### PART 1    GENERAL

- 1.1    REFERENCES
- 1.2    RELATED REQUIREMENTS
  - 1.2.1    Verification of Dimensions
  - 1.2.2    System Requirements
- 1.3    SUBMITTALS
- 1.4    QUALITY ASSURANCE
  - 1.4.1    Installation Drawings
  - 1.4.2    UL Listing or Label
- 1.5    SITE CONDITIONS

#### PART 2    PRODUCTS

- 2.1    MATERIALS
  - 2.1.1    Main and Bonding Conductors
  - 2.1.2    Copper
  - 2.1.3    Aluminum
- 2.2    COMPONENTS
  - 2.2.1    Air Terminals
  - 2.2.2    Ground Rods
  - 2.2.3    Grounding Plates
  - 2.2.4    Connections and Terminations
  - 2.2.5    Connector Fittings
  - 2.2.6    Lightning Protection Components

#### PART 3    EXECUTION

- 3.1    INTEGRAL SYSTEM
  - 3.1.1    Air Terminals
  - 3.1.2    Roof Conductors
  - 3.1.3    Down Conductors
  - 3.1.4    Interconnection of Metallic Parts
  - 3.1.5    Ground Connections

3.1.6	Grounding Electrodes
3.1.7	Grounding Plates
3.2	APPLICATIONS
3.2.1	Nonmetallic Exterior Walls with Metallic Roof
3.2.2	Metal Roofs with Metal Walls
3.2.3	Steel Frame Building
3.2.4	Ramps and Covered Passageways
3.2.5	Tanks and Towers
3.2.5.1	Wooden Tanks and Towers
3.2.5.2	Metal or Reinforced-Concrete Tanks and Towers
3.2.6	Stacks
3.2.6.1	Metal Stacks
3.2.6.2	Nonmetallic Stacks
3.3	INTERFACE WITH OTHER STRUCTURES
3.3.1	Interconnection of Metal Bodies
3.3.2	Fences
3.3.3	Exterior Overhead Pipe Lines
3.4	RESTORATION
3.5	FIELD QUALITY CONTROL
3.5.1	Grounding System Test
3.5.2	Lightning Protection System Inspection
-- End of Section Table of Contents --	

\*\*\*\*\*  
USACE / NAVFAC / AFCEA / NASA           UFGS-26 41 00.00 20 (April 2006)  
-----  
Preparing Activity:   NAVFAC           Replacing without change  
                                  UFGS-13100N (February 2003)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 18 July 2006

Latest change indicated by CHG tags.

\*\*\*\*\*

### SECTION 26 41 00.00 20

#### LIGHTNING PROTECTION SYSTEM 04/06

\*\*\*\*\*

NOTE: This guide specification covers the requirements for lightning protection systems for nonordnance naval facilities.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

\*\*\*\*\*

\*\*\*\*\*

NOTE: Show the following information on the project drawings:

1. Location of air terminals.
2. Location of down conductors.
3. Location of ground rods or grounding plates.
4. Location of ground loops (if any).

\*\*\*\*\*

## 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.

#### INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- |              |  |
|--------------|--|
| IEEE C135.30 | (1988) Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction   |
| 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  | (2005) National Electrical Code                     |
| NFPA 780 | (2004) Installation of Lightning Protection Systems |

#### UNDERWRITERS LABORATORIES (UL)

- |                   |   |
|-------------------|---|
| UL 467            | (2004) Grounding and Bonding Equipment                            |
| UL 96             | (2005) Lightning Protection Components                            |
| UL 96A            | (2001) Installation Requirements for Lightning Protection Systems |
| UL Elec Const Dir | (2003) 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. No departures shall be made 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 shall be manufacturer's latest UL approved design. Lightning protection system 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. Submittals should be kept 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.] The following shall be submitted 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

Each major component; G

#### SD-06 Test Reports

Grounding system test; G

Lightning protection system inspection; G

#### SD-07 Certificates

UL listing or label; G

### 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, 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 Elec Const Dir 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 coatings or oversize conductors. Where mechanical hazard is involved, increase conductor size to compensate for hazard 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).

#### 2.1.1 Main and Bonding Conductors

NFPA 780 and UL 96 Class I, Class II, or Class II modified materials as applicable.

#### 2.1.2 Copper

Provide copper conductors on nonmetallic stacks that do not weigh less than 144.83 kg per 305 meters 319 pounds per thousand feet, and provide cable such that the size of any strand in the cable is not less than No. 15 AWG. Provide thickness of web or ribbon on stacks that is not less than No. 12 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.)  
\*\*\*\*\*

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. When perforated strips are provided, use strips that are much wider than solid strips. Use a strip width that is at least twice that of the diameter of the perforations. Use an aluminum strip which has a thickness of not less than the diameter of No. 12 AWG and at least 40 mm 1 1/2 inches wide for connecting exposed water pipes.

### 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.

#### 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 conform to UL 467.] [galvanized ferrous rods conforming to IEEE 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 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.

#### 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.



## 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

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 air terminals on ridges, parapets, and around perimeter of building with flat roofs. When necessary to exceed this spacing, increase specified height of air terminals not less than 50 mm 2 inches for each 305 mm one foot of increase over 7620 mm 25 feet. 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.

#### 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. 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 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. [Rectangular structures having gable, hip, or gambrel roofs more than 33 m 110 feet long, provide at least one additional down conductor for each additional 15 m 50 feet of length or fraction thereof.] [Rectangular structures having French, flat, or sawtooth roofs 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.] [L- or T-shaped structure, provide at least one additional down conductor.] [H-shaped structure, at least two additional down conductors.] [Wing built structure, at least one additional down conductor for each wing.] [Irregularly shaped structures, 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 exceeding 5 m 16 feet in length, ending at air terminals. 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.

### 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 or 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 feet. Set ground rods not less than 610 mm 2 feet nor more than 3050 mm 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] [\_\_\_\_\_] 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 30 inches below grade, at a distance not less than 610 mm 2 feet nor more than 3050 mm 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. [Where so indicated, provide an alternate method for grounding electrodes in shallow soil by digging trenches radially from the building. Provide 1/0 bare copper cable arranged in a star pattern with the structure at the center for radial systems. Bury the radials at least 765 mm 30 inches below grade external to the structure. Lower ends of down conductors [or their equivalent in the form of metal strips or wires] are buried in trenches].

### 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. When no water system enter the structure, run ground connections from steel columns distributed equally around the perimeter of the structure. 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. However, ramps and covered passageways which are outside the zone of protection of a lightning protection system shall be provided with a lightning protection conforming to the requirements for lightning protection systems for buildings of similar construction. Place a down conductor and a driven ground at one of 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.

## 3.3 INTERFACE WITH OTHER STRUCTURES

### 3.3.1 Interconnection of Metal Bodies

Protect metal bodies when not within the zone of protection of air terminal. Bond metal bodies having an area of 0.258 square m 400 square inches or greater or a volume of 0.016387 cubic m 1000 cubic inches or greater to lightning protection system using main size conductors and a bonding plate having a surface contact area of not less than 1935 square mm 3 square inches. Make provisions to guard against the corrosive effect of bonding dissimilar metals. Bond metal bodies at their closest point to the lightning protection system using bonding conductors and fittings. Independently ground any metal body that exceeds 1525 mm 5 feet in any dimension, that is situated wholly within a building, and that does not at any point come within 1830 mm 6 feet of a lightning conductor or metal connected to a lightning protection system.

### 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 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.

## 3.5 FIELD QUALITY CONTROL

### 3.5.1 Grounding System Test

Test the grounding system to ensure continuity and that resistance to ground is not in excess of [10] [\_\_\_\_\_] 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.

### 3.5.2 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.

-- End of Section --