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USACE / NAVFAC / AFCEC / NASA UFGS-28 05 26.00 40 (August 2013)  
Change 1 - 05/14  
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Preparing Activity: NASA Superseding  
UFGS-28 05 26.00 40 (August 2010)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2014

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#### SECTION 28 05 26.00 40

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08/13

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#### SECTION 28 05 26.00 40

#### GROUNDING AND BONDING FOR ELECTRONIC SAFETY AND SECURITY 08/13

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NOTE: This guide specification covers the requirements for electrical system and equipment grounding including ground rods, grounding conductors, connectors, and other accessories. This section excludes instrumentation and static grounding systems.

Drawings should show plan layout of each grounding electrode, ground mat, ground grid, substation ground bus, interconnecting grounding conductor, and tap connections to steel building columns and outdoor electrical equipment. Detail drawings of ground mats and ground grids should show configuration, ground rod spacings, interconnecting cable and tap connections to substation yard fence, substation ground bus, and interior equipment.

When grounding systems as shown fail to achieve the desired measured resistance to ground, additional ground rods may be required.

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

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NOTE: If Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS is not included in the project specification, applicable requirements therefrom should be inserted and the first paragraph deleted. If Section 05 05 23.16 STRUCTURAL WELDING is not included in the project specification, applicable requirements therefrom should be inserted and the second paragraph deleted.  
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[ Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS applies to work specified in this section.

] [Section 05 05 23.16 STRUCTURAL WELDING applies to work specified in this section.

] 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.  
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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.

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2011; Amendment 2012) Specification for Filler Metals for Brazing and Braze Welding

ASTM INTERNATIONAL (ASTM)

ASTM B3 (2013) Standard Specification for Soft or Annealed Copper Wire

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81 (2012) Guide for Measuring Earth

Resistivity, Ground Impedance, and Earth  
Surface Potentials of a Ground System

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

RCBEA GUIDE (2004) NASA Reliability Centered Building  
and Equipment Acceptance Guide

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70 (2014; AMD 1 2013; Errata 1 2013; AMD 2  
2013; Errata 2 2013; AMD 3 2014; Errata 3  
2014) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-889 (1976; Rev B; Notice 2 1988; Notice 3  
1993) Dissimilar Metals

UNDERWRITERS LABORATORIES (UL)

UL 467 (2007) Grounding and Bonding Equipment

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.] [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:

SD-03 Product Data

Grounding Systems[; G][; G, [\_\_\_\_]]  
Ground Rods[; G][; G, [\_\_\_\_]]  
Ground Wires[; G][; G, [\_\_\_\_]]  
Connectors and Fasteners[; G][; G, [\_\_\_\_]]  
Bonding Materials[; G][; G, [\_\_\_\_]]

SD-06 Test Reports

Bond Resistance Test[; G][; G, [\_\_\_\_]]  
Ground Resistance Tests[; G][; G, [\_\_\_\_]]  
Ground Isolation Test[; G][; G, [\_\_\_\_]]  
Continuity Isolation Test[; G][; G, [\_\_\_\_]]

SD-08 Manufacturer's Instructions

Grounding Systems[; G][; G, [\_\_\_\_]]

SD-11 Closeout Submittals

Record Drawings[; G][; G, [\_\_\_\_]]

1.3 PREDICTIVE TESTING AND INSPECTION TECHNOLOGY REQUIREMENTS

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NOTE: The Predictive Testing and Inspection (PT&I) tests prescribed in Section 01 86 26.07 40 RELIABILITY CENTERED ACCEPTANCE FOR ELECTRICAL SYSTEMS are MANDATORY for all [NASA] [\_\_\_\_] assets and systems identified as Critical, Configured, or Mission Essential. If the system is non-critical, non-configured, and not mission essential, use sound engineering discretion to assess the value of adding these additional test and acceptance requirements. See Section 01 86 26.07 40 RELIABILITY CENTERED ACCEPTANCE FOR ELECTRICAL SYSTEMS for additional information regarding cost feasibility of PT&I.  
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This section contains systems and/or equipment components regulated by NASA's Reliability Centered Building and Equipment Acceptance Program. This program requires the use of Predictive Testing and Inspection (PT&I) technologies in conformance with RCBEA GUIDE to ensure building equipment and systems have been installed properly and contain no identifiable defects that shorten the design life of a system and/or its components.

Satisfactory completion of all acceptance requirements is required to obtain Government approval and acceptance of the Contractor's work.

Perform PT&I tests and provide submittals as specified in Section 01 86 26.07 40 RELIABILITY CENTERED ACCEPTANCE FOR ELECTRICAL SYSTEMS.

#### 1.4 MAINTENANCE MATERIALS SUBMITTAL

Submit manufacturer's instructions for the grounding systems including special provisions required to install equipment components and system packages. Within special notices, detail impedances, hazards and safety precautions.

### PART 2 PRODUCTS

Submit material, equipment, and fixture lists for grounding systems, including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information.

#### 2.1 EQUIPMENT

Submit equipment and performance data for the following items including life, test, system functional flows, safety features, and mechanical automated details.

##### 2.1.1 Ground Rods

[ Ensure ground rods conform to the requirements of [NFPA 70] [UL 467] [\_\_\_\_\_] .

] [Use copper-clad steel ground rods not less than 20 millimeter 3/4-inch in diameter and not less than [3000] [\_\_\_\_\_] millimeter [10] [\_\_\_\_\_] -feet long per section. Ensure ground rods are clean and smooth and have a cone-shaped point on the first section. Ensure rods are die-stamped near the top with the name or trademark of the manufacturer and the length of the rod in millimeters feet.

##### ] 2.1.2 Ground Wires

Ensure ground wires are in accordance with Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL.

Ground and bond wires for substations, main panels and distribution points, and ground rod connections are annealed bare copper conforming to ASTM B3, stranded, with 98 percent conductivity. Wire size is in accordance with the grounding requirements of NFPA 70.

Ground wires for equipment receptacles for non-current carrying hardware, installed in conduit is soft drawn copper, in accordance with ASTM B3, stranded, with green insulation. Note wire size.

##### 2.1.3 Connectors And Fasteners

Ensure grounding and bonding fasteners and connectors conform to the requirements of UL 467, and Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL.

Use [copper] [bronze] grounding and bonding fasteners.

Use copper bonding straps and jumpers with a cross-sectional area of not less than 4.12 millimeter diameter No. 6 AWG. Bonding straps and jumpers for shock-mounted devices with [pivot] [hinged] [swivel] joints are made of [flat] [tinned-copper] [woven-wire braid] [flexible stranded] wire.

## PART 3 EXECUTION

### 3.1 BONDING AND GROUNDING

Ensure bonding and grounding requirements are in accordance with NFPA 70.

### 3.2 INSTALLATION

#### 3.2.1 Grounding Electrodes

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**NOTE: In locations where existing underground utilities, equipment or structures may be damaged, ground rod installation should be accomplished using the water jetting method.**  
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Grounding electrodes include ground rods installed expressly for grounding systems. [Install ground rods using a water jetting procedure.]

Minimum ground rod section are [3000] [\_\_\_\_\_] millimeters [10] [\_\_\_\_\_] -feet. Thread sections together and exothermically fusion weld.

[ Install ground rods so that the top of the rod is [100] [\_\_\_\_\_] millimeter [4] [\_\_\_\_\_] -inches above grade.

] [Install ground rods so that the top of the rod is not less than [450] [\_\_\_\_\_] millimeter [18] [\_\_\_\_\_] -inches below finished grade.

#### ] 3.2.2 Ground Grids

Ground grids consist of a series of ground rods installed with interconnecting grounding conductors between ground rods. Space ground rods as noted.

Do not bury ground grid less than [450] [\_\_\_\_\_] millimeter [18] [\_\_\_\_\_] -inches below the finish grade. Provide grounding conductors not less than [11.7] [\_\_\_\_\_] millimeter diameter (No. [4/0] [\_\_\_\_\_] AWG) No. [4/0] [\_\_\_\_\_] AWG and are exothermically fusion welded together at crossover points and to ground rods.

#### 3.2.3 Building Grounds

Ground the steel framework of the building with a driven ground rod at the base of every corner column and intermediate exterior columns at distances not greater than [18,000] [\_\_\_\_\_] millimeter [60] [\_\_\_\_\_] -feet apart. Electrically connect grounding conductor to each ground rod and to each steel column and extend around the perimeter of the building. Ensure grounding-conductor loop around the perimeter of the building is not less than [11.7] [\_\_\_\_\_] millimeter diameter (No. [4/0] [\_\_\_\_\_] AWG) No. [4/0] [\_\_\_\_\_] AWG. Ensure tap connections from the ground loop to the building steel are not less than [11.7] [\_\_\_\_\_] millimeter diameter (No. [4/0] [\_\_\_\_\_] AWG) No. [4/0] [\_\_\_\_\_] AWG.

Bury building ground no less than 450 millimeter 18 inches below grade and [600] [ ] millimeter [2] [ ] feet from the building foundation. Interconnecting grounding conductor between ground grid and building grounds cannot be less than [11.7] [ ] millimeter diameter (No. [4/0] [ ] AWG) No. [4/0] [ ] AWG.

### 3.2.4 Equipment Grounding

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**NOTE: This paragraph specifies a "Case" ground. A Case ground is where grounding is critical such as fueling areas, pads, etc. A modification such as an office building or an administrative area would not require the additional ground.**

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[ In addition to the green colored equipment grounding conductor required in each raceway and sized in accordance with Table 250.122 of the NEC, bond each panelboard/ switchboard enclosure, transformer housing, motor housing, disconnect, starter, and other electrical equipment, addressed under this contract, to the grounding system with a stranded copper conductor, routed external to the feeder raceway.

] Ensure metallic raceway systems have electrical continuity with equipment, and equipment is individually and directly connected to the building ground, independent of the raceway system.

Individually and directly connect enclosures for panelboards to the building ground. Install a grounding conductor sized not less than [6.54] [ ] millimeter diameter (No. [2] [ ] AWG) No. [2] [ ] AWG and connected from the building ground to a copper ground-bus terminal strip located in each panelboard.

Ground polarized receptacles, lighting fixtures, and equipment enclosures with an identified (green color) insulated conductor, not smaller than [2.03] [ ] millimeter diameter (No. [12] [ ] AWG) No. [12] [ ] AWG, connected to the branch circuit ground-bus terminal strip. Isolate ground-bus terminal strip in each panelboard enclosure and independent of the system neutral terminal strip.

Individually and directly connect indoor substations, transformers, switchboard frames, switchgear assemblies, motors, motor control centers, air compressors, air handlers, refrigerated air dryers, generators, frames and tracks of cranes, and [ ] to the building ground. Ensure the current-carrying capacity of the grounding conductor is the same as the current-carrying capacity of the power conductors for circuits utilizing power lines size [6.54] [ ] millimeter diameter (No. [2] [ ] AWG) No. [2] [ ] AWG and smaller. For circuits with power wiring larger than [6.54] [ ] millimeter diameter (No. [2] [ ] AWG) No. [2] [ ] AWG, ensure the grounding conductor is in accordance with NFPA 70, except that the grounding conductor is not smaller than [6.54] [ ] millimeter diameter (No. [2] [ ] AWG) No. [2] [ ] AWG.

Noncurrent carrying metallic parts of electrical equipment, including metallic cable sheaths, conduit, raceways, and electrical structural members, are bonded together and connected to the ground grid or ground connection rods.

Install secure ground systems for power and instrumentation. Independently connect each system to the building counterpoise as shown.

Secure ground systems consists of unspliced ground wires in individual welded or epoxied conduit runs from the secure area to the building counterpoise. Welding and epoxying conforms to Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL.

### 3.2.5 Grounding Connections

Bond ground connections connections in accordance with paragraph entitled, "Bonding, Materials and Methods," of this section.

[Weld] [Silver-solder] ground connections that are buried or in inaccessible locations.

In accessible locations, bolt connections together. Use cast-copper-alloy clamp lugs connections for steel building columns in accessible locations that are [bolted] [exothermically fusion-welded] to the structure.

Clean, grease, and remove foreign matter from ground connection surfaces. Do not penetrate clad material in the cleaning process. Make connection between like metals where possible. Where dissimilar metals are welded, brazed, or clamped, follow the weld kit manufacturer's instructions. Ensure connections between dissimilar metals do not produce galvanic action in accordance with MIL-STD-889.

### 3.2.6 Bonding Materials And Methods

Accomplish bonding of metal surfaces by [brazing] [welding] [clamping] [structural joining methods].

#### 3.2.6.1 Brazing

Ensure brazing solder conforms to AWS A5.8/A5.8M [\_\_\_\_\_].

#### 3.2.6.2 Welding

Weld using the exothermic process. Within the welding procedure, include the proper mold and powder charge and conform to the manufacturer's recommendations.

Use welding processes of the exothermic fusion type that makes a connection without corroding or loosening. Ensure process joins all strands and not causes the parts to be damaged or weakened. Completed connection or joint is equal or larger in size than the conductors joined and have the same current-carrying capacity as the largest conductor. Paint the buried ground connections with a bitumastic paint.

#### 3.2.6.3 Clamping

In external locations, use clamping only where a disconnect type of connection is required. Connection device may utilize [spring-loaded jaws] [threaded fasteners]. Construct device such that positive contact pressure is maintained at all times. Use machine bolts with [tooth-type] [spring-type] lockwashers.

#### 3.2.6.4 Structural Joining Methods

Consider joints made with high-strength structural bolts, and clean unpainted faying surfaces sufficiently bonded. Install a jumper across the joint in the form of a [5.19] [ ] millimeter diameter (No. [4] [ ] AWG) No. [4] [ ] AWG bare copper wire [exothermically welded] [bond welded with a 6 millimeter 1/4-inch or larger fillet weld, with a [50] [ ] millimeter [2] [ ]-inch minimum length across the connection] at each end to the surfaces involved spanning the connection wire jumpers used across joints employing miscellaneous machine bolts.

#### 3.2.6.5 Cleaning of Bonding Surfaces

Thoroughly clean surfaces that comprise the bond before joining. Apply an appropriate abrasive with gentle and uniform pressure to ensure a smooth and uniform surface. Do not remove excessive metal from the surface. Clean clad metals in such a manner that the cladding material is not penetrated by the cleaning process. Then clean bare metal with an appropriate solvent to remove any grease, oil, dirt, corrosion preventives, and other contaminants. Bond to the cleaned area within one hour after cleaning. Seal joint and refinish the exposed surfaces within two hours of exposure to prevent oxidation. When additional time is required, apply a corrosion preventive compound until the area can be refinished.

#### 3.2.6.6 Bonding Straps and Jumpers

Install jumpers such that the vibration by the shock-mounted device does not change its electrical characteristics.

[Brazed] [Welded] bonds for outdoor locations unless a disconnect type of connection is required. When a disconnect is required, use clamping with bolts. Insert a tooth-type lockwasher between the strap and metallic member for each bolt.

Bond straps directly to the basic structure and do not penetrate any adjacent parts. Install straps in an area that is accessible for maintenance.

Use single straps for the bonds and install such that they do not restrict movement of structural members. Do not connect two or more straps in series.

Install straps such that they do not weaken structural members to which they are attached.

#### 3.2.6.7 Equipment and Enclosure Bonding

Bond each metallic enclosure and all electrical equipment to ground. Make at least one copper connection from the system ground point to one or more enclosures in the area such that all enclosures and equipment provide a low-impedance path to ground when properly bonded together.

#### 3.2.6.8 Bonding of Conduit and Raceway Systems

Bond all metal conduit, fittings, junction boxes, outlet boxes, armored and metal sheathed cable, and other raceways. Take care to ensure adequate electrical contact at the joints and terminations.

For rigid metal conduit and terminations, ensure threaded connections are

wrench-tight with no exposed threads. Ream all ends of the conduit to remove burrs and rough edges. Bond conduits entering boxes and enclosures to the box with [bonding-type locknuts, one outside and one inside.] [locknuts and grounding-type bushings.] Locknuts that gouge into the metal box when tightened are not acceptable.

Conduit systems that are interrupted by PVC dielectric links are bonded separately on either side of the link. Do not jumper the dielectric link.

Install flexible metal conduit with an integral grounding conductor.

#### 3.2.6.9 Cable Tray Bonding

Bond cable tray sections together. Cable tray sections in tandem assembly are considered as having electrical continuity when these sections are bonded with the appropriate bolts. Install bond straps across expansion joints. Bond cable trays to the building ground system.

#### 3.2.6.10 Protection of Finished Bonds

Protect finished bonds by painting to match the original finish after the bond is made.

### 3.3 FIELD TESTS

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NOTE: If the specified system is identified as critical, configured, or mission essential, use Section 01 86 26.07 40 RELIABILITY CENTERED ACCEPTANCE FOR ELECTRICAL SYSTEMS to establish predictive and acceptance testing criteria, above and beyond that listed below.  
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Perform PT&I tests and provide submittals as specified in Section 01 86 26.07 40 RELIABILITY CENTERED ACCEPTANCE FOR ELECTRICAL SYSTEMS.

Submit test reports for the following tests on grounding systems. Within the report include certified record of ground-resistance tests on each driven ground rod, ground rod assembly, and other grounding electrodes. Include within the record the number of rods driven and their depth at each location to meet the required resistance-to-ground measurements specified. Include a statement describing the condition of the soil at the time of measurement.

Perform the following tests in the presence of the Contracting Officer.

#### 3.3.1 Bond Resistance Test

Resistance of any bond connection cannot exceed [0.5] [\_\_\_\_\_] milliohm. Rework bonds that exceed this resistance at no additional cost to the Government.

#### 3.3.2 Ground Resistance Tests

Test grounding systems for ground resistance. Total resistance from any point on the ground network to the building counterpoise cannot exceed [50] [\_\_\_\_\_] milliohms.

Make ground resistance and counterpoise tests during dry weather, and no sooner than [48] [\_\_\_\_\_] hours after rainfall. Conduct tests using the ratio method that measures the ratio of the resistance to earth of an auxiliary test electrode to the series resistance of the electrode under test and a second auxiliary electrode. Perform measurements in accordance with IEEE 81.

Use self-contained indicating instrument, include a direct-current generator, synchronized current and potential reversers, crossed-current and potential coils, direct-reading ohmmeter, series resistors, and range-selector switch. Calibrate direct-reading ohmmeter for ranges of 0 to 20 ohms and 0 to 200 ohms.

Place auxiliary grounding electrodes in accordance with instrument manufacturer's recommendations but not less than [15,000] [\_\_\_\_\_] millimeter [50] [\_\_\_\_\_] -feet apart, in accordance with IEEE 81.

#### 3.3.3 Ground Isolation Test

Test ground systems for isolation from other ground systems.

#### 3.3.4 Continuity Isolation Test

Perform continuity test on all power receptacles to ensure that the ground terminals are properly grounded to the facility ground system.

### 3.4 CLOSEOUT ACTIVITIES

Submit record drawings indicating the location of ground rods, mats, grids, building ground bus, supplementary grounding electrodes, steel building columns, and other metal structures connected to the grounding system.

Identify the location of each ground rod and ground-rod assembly and other grounding electrodes by letter in alphabetical order and keyed to the record of ground-resistance tests.

-- End of Section --