

3.8 FIELD TESTS

3.8.1 Bond Resistance Test

3.8.2 Ground Resistance Tests

3.8.3 Ground Isolation Test

3.8.4 Continuity Isolation Test

-- End of Section Table of Contents --

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UNIFIED FACILITIES GUIDE SPECIFICATIONS

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SECTION 28 05 26.00 40

GROUNDING AND BONDING FOR ELECTRONIC SAFETY AND SECURITY 08/10

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

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 \(CCR\)](#).

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 WELDING SOCIETY (AWS)

AWS A5.8/A5.8M (2004) Specification for Filler Metals for Brazing and Braze Welding

ASTM INTERNATIONAL (ASTM)

ASTM B 3 (2001; R 2007) Standard Specification for Soft or Annealed Copper Wire

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81 (1983) 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 (2011) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-889 (1993; Rev B, Notice 3) Dissimilar Metals

UNDERWRITERS LABORATORIES (UL)

UL 467 (2007) Grounding and Bonding Equipment

1.2 GENERAL REQUIREMENTS

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 WELDING, STRUCTURAL is not included in the project specification, applicable requirements therefrom should be inserted and the second paragraph deleted.

[Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS applies to work specified in this section.]

[Section 05 05 23 WELDING, STRUCTURAL applies to work specified in this section.]

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.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

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.

SD-02 Shop Drawings

Submit [Record Drawings](#) in accordance with paragraph entitled, "Drawings," of this section.

SD-03 Product Data

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

Submit Manufacturer's catalog data for the following items:

[Ground Rods](#)

[Ground Wires](#)

[Connectors and Fasteners](#)

[Bonding](#)

SD-06 Test Reports

Submit Test Reports for the following tests on grounding systems in accordance with the paragraph entitled, "Field Tests," of this section. 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.

[Bond Resistance Test](#)

[Ground Resistance Tests](#)

[Ground Isolation Test](#)

[Continuity Isolation Test](#)

SD-08 Manufacturer's Instructions

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.

1.4 DRAWINGS

[Record Drawings](#) must indicate 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.

1.5 PREDICTIVE TESTING AND INSPECTION TECHNOLOGY REQUIREMENTS

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.

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 installed by the Contractor 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.

PART 2 PRODUCTS

2.1 GROUND RODS

[Ground rods must conform to the requirements of [NFPA 70] [UL 467] [_____]].

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

] 2.2 GROUND WIRES

Ground wires must be 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 must be annealed bare copper conforming to ASTM B 3, stranded, with 98 percent conductivity. Wire size must be in accordance with the grounding requirements of NFPA 70.

Ground wires for equipment receptacles for noncurrent carrying hardware, installed in conduit must be soft drawn copper, in accordance with ASTM B 3, stranded, with green insulation. Note wire size.

2.3 CONNECTORS AND FASTENERS

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

Grounding and bonding fasteners must be [copper] [bronze].

Bonding straps and jumpers must be copper and have 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 must be made of [flat] [tinned-copper] [woven-wire braid] [flexible stranded] wire.

PART 3 EXECUTION

3.1 BONDING AND GROUNDING

Bonding and grounding requirements must be in accordance with NFPA 70.

3.2 GROUNDING ELECTRODES

NOTE: In locations where existing underground utilities, equipment or structures may be damaged, ground rod installation should be accomplished using the water jetting method.

Grounding electrodes must include ground rods installed expressly for grounding systems. [Install ground rods using a water jetting procedure.]

Minimum ground rod section must be [3000] [_____] millimeter [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.]

3.3 GROUND GRIDS

Ground grids must 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. Grounding conductors must not be less than [11.7] [_____] millimeter diameter (No. [4/0] [_____] AWG) No. [4/0] [_____] AWG and must be exothermically fusion welded together at crossover points and to ground rods.

3.4 BUILDING GROUNDS

Steel framework of the building must be grounded 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.

Grounding-conductor loop around the perimeter of the building must not be less than [11.7] [] millimeter diameter (No. [4/0] [] AWG) No. [4/0] [] AWG. Tap connections from the ground loop to the building steel must not be 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 must not be less than [11.7] [] millimeter diameter (No. [4/0] [] AWG) No. [4/0] [] AWG.

3.5 EQUIPMENT GROUNDING

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.

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

Metallic raceway systems must have electrical continuity with equipment individually and be directly connected to the building ground, independent of the raceway system.

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

Polarized receptacles, lighting fixtures, and equipment enclosures must be grounded 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. Ground-bus terminal strip in each panelboard enclosure must be isolated and independent of the system neutral terminal strip.

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 [] must be individually and directly connected to the building ground. Current-carrying capacity of the grounding conductor must be 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, the grounding conductor must be in accordance with NFPA 70, except that the grounding conductor must not be 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, must be 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 must consist of unspliced ground wires in individual welded or epoxied conduit runs from the secure area to the building counterpoise. Welding and epoxying must conform to Section 26 05 00.00 40 COMMON WORK RESULTS FOR ELECTRICAL.

3.6 GROUNDING CONNECTIONS

Ground connections must be bonded connections in accordance with paragraph entitled, "Bonding," of this section.

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

Bolt connections in accessible locations. Connections to steel building columns in accessible locations must be cast-copper-alloy clamp lugs [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. Connections between dissimilar metals must not produce galvanic action in accordance with MIL-STD-889.

3.7 BONDING

3.7.1 Type of Bonds

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

3.7.1.1 Brazing

Brazing solder must conform to AWS A5.8/A5.8M [_____] .

3.7.1.2 Welding

Welding must be by the exothermic process. Within the welding procedure, include the proper mold and powder charge and conform to the manufacturer's recommendations.

Welding processes must be of the exothermic fusion type that will make a connection without corroding or loosening. Process must join all strands and not cause the parts to be damaged or weakened. Completed connection or

joint must be equal or larger in size than the conductors joined and have the same current-carrying capacity as the largest conductor. Paint buried ground connections with a bitumastic paint.

3.7.1.3 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.

3.7.1.4 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.

3.7.2 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 must be made 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.

3.7.3 Bonding Straps and Jumpers

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

[Brazed] [Weld] 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 will not restrict movement of structural members. Do not connect two or more straps in series.

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

3.7.4 Equipment and Enclosure Bonding

Each metallic enclosure and all electrical equipment must be bonded to ground. At least one copper connection must be made 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.

3.7.5 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.

3.7.5.1 Rigid Metal Conduit and Terminations

Threaded connections must be wrench-tight and there must be no exposed threads. Ream all ends of the conduit to remove burrs and rough edges. Conduits entering boxes and enclosures must be bonded 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 must be bonded separately on either side of the link. Dielectric link must not be jumpered.

3.7.5.2 Flexible Metal Conduit

Flexible conduit must have an integral grounding conductor.

3.7.6 Cable Tray Bonding

Bond cable tray sections together. Cable tray sections in tandem assembly must be 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.

3.7.7 Protection of Finished Bonds

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

3.8 FIELD TESTS

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.

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

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

3.8.1 Bond Resistance Test

Resistance of any bond connection must not exceed [0.5] [_____] milliohm. Rework bonds that exceed this resistance at no additional cost to the Government.

3.8.2 Ground Resistance Tests

Test **Grounding systems** for ground resistance. Total resistance from any point on the ground network to the building counterpoise must not exceed [50] [_____] milliohms.

Ground resistance and counterpoise tests must be made 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**.

Indicating instrument must be self-contained and 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**.

3.8.3 Ground Isolation Test

Test ground systems for isolation from other ground systems.

3.8.4 Continuity Isolation Test

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

-- End of Section --