

GROUNDING AND BONDING

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PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.

1.2 SUMMARY

- A. This Section includes grounding of electrical systems and equipment. Grounding requirements specified in this Section may be supplemented by special requirements of systems described in other Sections.

- B. Related Sections include the following:

1. Division 26 Section "Underground Ducts and Utility Structures" for ground test wells.
2. Division 26 Section "Electrical General Requirements".
3. Division 26 Section "Conductors and Cables".

1.3 REFERENCES

- A. ASTM B 3: Specification for Soft or Annealed Copper Wire.
- B. ASTM B 8: Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard or Soft.
- C. ASTM B 33: Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes.
- D. ASTM B 187: Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes.

- E. IEEE 81: Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
  - F. IEEE 142: Grounding of Industrial and Commercial Power Systems.
  - G. IEEE 837: Qualifying Permanent Connections Used in Substation Grounding.
  - H. IEEE 1100 – 1992: Recommended Practice for Powering and Grounding Sensitive Electronic Equipment.
  - I. IEEE C2: National Electrical Safety Code.
  - J. NETA MTS – 2001: Maintenance Testing Specifications.
  - K. NFPA 70: National Electrical Code.
  - L. NFPA 70B: Recommended Practice for Electrical Equipment Maintenance.
  - M. TIA/EIA 607: Commercial Building Grounding and Bonding Requirements Standard.
  - N. UL 467: Grounding and Bonding Equipment.
  - O. UL 486 A: Wire Connectors and Soldering Lugs for Use with Copper Conductors.
  - P. UL 486B: Wire Connectors for Use with Aluminum Conductors.
- 1.4 SUBMITTALS
- A. Product Data: For each type of product indicated.
  - B. Product Data: For the following:
    - 1. Ground rods.
  - C. Qualification Data: For firms and persons specified in "Quality Assurance" Article.
  - D. Field Test Reports: Submit written test reports to include the following:
    - 1. Test procedures used.
    - 2. Test results that comply with requirements.
    - 3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.
    - 4. Indicate overall system resistance to ground.
    - 5. Indicate overall Telecommunications system resistance to ground.
- 1.5 PROJECT RECORD DOCUMENTS
- A. Submit under provisions of Division 26 "Electrical General Requirements".
  - B. Accurately record actual locations of grounding electrodes and connections to building steel.

1.6 QUALITY ASSURANCE

- A. Testing Agency Qualifications: Refer to specification section "Electrical Testing."
- B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.
  - 1. Comply with UL 467.
- C. Comply with NFPA 70; for overhead-line construction and medium-voltage underground construction, comply with IEEE C2.
- D. Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system.
- E. Comply with ANSI/TIA/EIA-607 "Standard for Commercial Building Grounding and Bonding requirements for telecommunications".
- F. Comply with ANSI/IEEE 1100 -1992 "Powering and Grounding Sensitive Electronic Equipment".

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
  - 1. Grounding Conductors and Cables:
    - a. Refer to Division 26 Section "Conductors and Cables".
  - 2. Grounding Rods:
    - a. American Electric-Blackburn.
    - b. Apache Grounding/Erico Inc.
    - c. Chance/Hubbell.
  - 3. Mechanical Connectors:
    - a. American Electric-Blackburn.
    - b. Burndy.
    - c. Chance/Hubbell.
  - 4. Exothermic Connections:
    - a. Cadweld.

2.2 GROUNDING CONDUCTORS

- A. For insulated conductors, comply with Division 26 Section "Conductors and Cables."
- B. Material: Copper.
- C. Equipment Grounding Conductors: Insulated with green-colored insulation.

- D. Isolated Ground Conductors: Insulated with green-colored insulation with yellow stripe. On feeders with isolated ground, use colored tape, alternating bands of green and yellow tape to provide a minimum of three bands of green and two bands of yellow.
- E. Grounding Electrode Conductors: Stranded cable.
- F. Underground Conductors: Bare, stranded, copper unless otherwise indicated.
- G. Bare Copper Conductors: Comply with the following:
  - 1. Solid Conductors: ASTM B 3.
  - 2. Assembly of Stranded Conductors: ASTM B 8.
  - 3. Tinned Conductors: ASTM B 33.
- H. Copper Bonding Conductors: As follows:
  - 1. Bonding Conductor: Stranded copper conductor; size per the NEC.
  - 2. Bonding Jumper: Bare copper tape, braided bare copper conductors, terminated with copper ferrules; size per the NEC.
  - 3. Tinned Bonding Jumper: Tinned-copper tape, braided copper conductors, terminated with copper ferrules; size per the NEC.
- I. Grounding Bus: Bare, annealed copper bars of rectangular cross section, with insulators.
- J. Telecommunications Main Grounding Busbar (TMGB)
  - 1. 48" (min) x 4" x 1/4" tin plated, copper busbar with three rows of 1/4 x 20 tapped holes 3" on center.

### 2.3 CONNECTOR PRODUCTS

- A. Comply with IEEE 837 and UL 467; listed for use for specific types, sizes, and combinations of conductors and connected items.
- B. Bolted Connectors: Bolted-pressure-type connectors, or compression type.
- C. Welded Connectors: Exothermic-welded type, in kit form, and selected for the specific application per manufacturer's written instructions.
- D. Compression-Type Connectors: Pure, wrought copper, per ASTM B187.

### 2.4 GROUNDING ELECTRODES

- A. Ground Rods: Copper-clad steel.
  - 1. Size: 3/4 in diameter.
  - 2. Length: 120 inches.

## PART 3 - EXECUTION

### 3.1 EQUIPMENT GROUNDING

- A. Comply with NFPA 70, Article 250, for types, sizes, and quantities of equipment grounding conductors, unless specific types, larger sizes, or more conductors than required by NFPA 70 are indicated.
- B. Use only copper conductors for both insulated and bare grounding conductors in direct contact with earth, concrete, masonry, crushed stone, and similar materials.
- C. Underground Grounding Conductors: No. 2/0 AWG minimum. Bury at least 24 inches below grade or bury 12 inches above duct bank when installed as part of the duct bank.
- D. In raceways, use insulated equipment grounding conductors.
- E. Install equipment grounding conductors in all feeders and circuits. Terminate each end on suitable lugs, bus or bushing.
- F. Busway Supply Circuits: Install insulated equipment grounding conductor from the grounding bus in the switchgear, switchboard, or distribution panel to equipment grounding bar terminal on busway.
- G. Nonmetallic Raceways: Install an equipment grounding conductor in nonmetallic raceways unless they are designated for telephone or data cables.
- H. Verify specific equipment grounding requirements with the manufacturer's recommendations.

### 3.2 CONNECTIONS

- A. General: Make connections so galvanic action or electrolysis possibility is minimized. Select connectors, connection hardware, conductors, and connection methods so metals in direct contact will be galvanically compatible.
  - 1. Use electroplated or hot-tin-coated materials to ensure high conductivity and to make contact points closer to order of galvanic series.
  - 2. Make connections with clean, bare metal at points of contact.
  - 3. Make aluminum-to-steel connections with stainless-steel separators and mechanical clamps.
  - 4. Make aluminum-to-galvanized steel connections with tin-plated copper jumpers and mechanical clamps.
  - 5. Coat and seal connections having dissimilar metals with inert material to prevent future penetration of moisture to contact surfaces.
- B. Exothermic-Welded Connections: Use for connections to structural steel and for underground connections, except those at test wells. Comply with manufacturer's written instructions. Welds that are puffed up or that show convex surfaces indicating improper cleaning are not acceptable.
- C. Equipment Grounding Conductor Terminations

1. Use solderless pressure connectors with insulating covers for copper conductor splices and taps, 8 AWG and larger.
  2. Use insulated spring wire connectors with plastic caps for copper conductor splices and taps, 10 AWG and smaller.
- D. Noncontact Metal Raceway Terminations: If metallic raceways terminate at metal housings without mechanical and electrical connection to housing, terminate each conduit with a grounding bushing. Connect grounding bushings with a bare grounding conductor to grounding bus or terminal in housing. Bond electrically noncontinuous conduits at entrances and exits with grounding bushings and bare grounding conductors, unless otherwise indicated.
- E. Tighten screws and bolts for grounding and bonding connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.
- F. Compression-Type Connections: Use hydraulic compression tools to provide correct circumferential pressure for compression connectors. Use tools and dies recommended by connector manufacturer. Provide embossing die code or other standard method to make a visible indication that a connector has been adequately compressed on grounding conductor.
- G. Moisture Protection: If insulated grounding conductors are connected to ground rods or grounding buses, insulate entire area of connection and seal against moisture penetration of insulation and cable.
- 3.3 INSTALLATION
- A. Equipotential Ground: Interconnect grounding electrodes to form one, electrically continuous, equipotential grounding electrode system. Grounding electrodes to be interconnected include:
1. Ground rods.
- B. Ground Rods: Install at least three rods spaced at least one-rod length from each other and located at least the same distance from other grounding electrodes.
1. Verify that final backfill and compaction has been complete before driving ground rods.
  2. Drive ground rods until tops are 2 inches below finished floor or final grade, unless otherwise indicated.
  3. Interconnect ground rods with grounding electrode conductors. Use exothermic welds, except at test wells and as otherwise indicated. Make connections without exposing steel or damaging copper coating.
- C. Grounding Conductors: Route along shortest and straightest paths possible, unless otherwise indicated. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage. Install in conduit where routed above grade.
- D. Bonding Straps and Jumpers: Install so vibration by equipment mounted on vibration isolation hangers and supports is not transmitted to rigidly mounted equipment. Use exothermic-welded connectors for outdoor locations, unless a disconnect-type connection is required; then, use a bolted clamp. Bond straps directly to the basic structure taking care not to penetrate any adjacent parts. Install straps only in locations accessible for maintenance.
- E. Metal Water Service Pipe: Provide insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to

building. Connect grounding conductors to main metal water service pipes by grounding clamp connectors. Where a dielectric main water fitting is installed, connect grounding conductor to street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end.

- F. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with grounding clamp connectors.
- G. Bond each aboveground portion of gas piping system upstream from equipment shutoff valve.
- H. Grounding Bus:
  - 1. Install grounding bus in the locations listed below and elsewhere as indicated:
    - a. Electrical equipment rooms.
    - b. Telephone equipment rooms.
  - 2. Use insulated spacer; space 1 inch from wall and support from wall 6 inches above finished floor, unless otherwise indicated.
- I. Equipment Grounding: Provide a permanent and continuous bonding of conductor enclosures, equipment frames, power distribution equipment ground busses, cable trays, metallic raceways, and other non-current carrying metallic parts of the electrical system.

#### 3.4 UNDERGROUND DISTRIBUTION SYSTEM GROUNDING

- A. Manholes and Handholes: Install a driven ground rod close to wall, inside manhole, and set rod depth so 4 inches will extend above finished floor. If necessary, install ground rod before manhole is placed and provide a No. 1/0 AWG conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive tape or heat-shrunk insulating sleeve from 2 inches above to 6 inches below concrete. Seal floor opening with waterproof, nonshrink grout.
- B. Connections to Manhole Components: Connect all exposed-metal parts, such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or handhole, to ground rod or grounding conductor. Make connections with No. 4 AWG minimum conductor. Train conductors level or plumb around corners and fasten to manhole walls. Connect to cable armor and cable shields as recommended by manufacturer of splicing and termination kits.
- C. Pad-Mounted Transformers and Switches: Install four ground rods and counterpoise circling pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with transformers/substations by connecting them to underground cable and grounding electrodes. Use not less than a No. 2 AWG conductor for counterpoise and for taps to equipment ground pad. Bury counterpoise not less than 18 inches below grade and 6 inches from the foundation.

#### 3.5 TELECOMMUNICATIONS GROUNDING

- A. Telecommunications Grounding System: The telecommunications grounding system shall consist of:
  - 1. Telecommunications Main Grounding Busbar (TMGB) located in the main telecommunications room near the telecommunications service entrance. Bond to the main building electrical grounding electrode system via a No. 3/0 AWG copper ground conductor.

2. Bonding of all equipment racks, raceways, non-current carrying metallic equipment and surge protection devices within the telecommunications room to the TGB's or TMGB using approved bonding conductors. Each piece of equipment shall be bonded individually directly to the ground bus.
- B. All bonding connections shall be installed at an accessible location for inspection and maintenance.
  - C. All telecommunications bonding connections shall be of an approved mechanical type connection. Do not use exothermic welds unless specifically indicated on the Drawings.
  - D. The physical routing shall, in general, follow the same path as the backbone cable system.
  - E. Bond each TGB directly to the building steel with a No. 6 AWG conductor.
  - F. Do not use TGB's as a power system ground connection unless specifically noted on the Drawings.
  - G. All bonding connectors and conductors shall be UL listed for the purpose intended.
  - H. Mount TMGB bus to backboard or wall using 2" standoff insulators.
  - I. Individually bond each piece of non-current carrying metallic equipment in the Telecommunications Room to the TGB.
  - J. Install continuous cable from the TMGB to the furthest TGB. Bond all TGB's to TBB with bare No. 3/0 AWG copper ground conductor and T-tap grounding hardware.
- 3.6 FIELD QUALITY CONTROL
- A. Testing: Perform the following field quality control tests in accordance with Division 26 section "Electrical Testing"
    1. Inspect grounding and bonding system conductors and connections for tightness and proper installation and for compliance with the Drawings and Specifications.
    2. After installing grounding system but before permanent electrical circuitry has been energized, test for compliance with requirements.
      - a. Test completed grounding system at each location where a maximum ground-resistance level is specified, at service disconnect enclosure grounding terminal.
      - b. Measure ground resistance not less than two full days after the last trace of precipitation, and without the soil being moistened by any means other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance.
      - c. Perform ground-impedance measurements utilizing either the intersecting curves method of the slope method. (Ref. Nos. 40 and 41 in IEEE Std. 81).
      - d. Equipment Grounds: Utilize two-point method of IEEE 81. Measure between equipment ground being testing and known low-impedance grounding electrode or system.
    3. Provide drawings locating each ground rod and ground rod assembly and other grounding electrodes, identify each by letter in alphabetical order, and key to the record of tests and observations. Include the number of rods driven and their depth at each location and include observations of weather and other phenomena that may affect test results. Describe measures taken to improve test results.

- a. Equipment Rated 500 kVA and Less: 10 ohms.
  - b. Equipment Rated 500 to 1000 kVA: 5 ohms.
  - c. Equipment Rated More Than 1000 kVA: 3 ohms.
  - d. Substations and Pad-Mounted Switching Equipment: 5 ohms.
  - e. Manhole Grounds: 10 ohms.
  - f. The telecommunications grounding system shall have a maximum resistance of 1 ohm as measured from the TMGB ground to earth ground.
4. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify Architect promptly and include recommendations to reduce ground resistance.

### 3.7 GRADING AND PLANTING

- A. Restore surface features, including vegetation, at areas disturbed by Work of this Section. Reestablish original grades, unless otherwise indicated. If sod has been removed, replace it as soon as possible after backfilling is completed. Restore areas disturbed by trenching, storing of dirt, cable laying, and other activities to their original condition. Include application of topsoil, fertilizer, lime, seed, sod, sprig, and mulch. Comply with Division 2 Section "Landscaping." Maintain restored surfaces. Restore disturbed paving as indicated.

### **GROUNDING SYSTEM** **MARCH 17, 2008**

1. Drawings and Specifications: Drawings shall show ground systems, protective conduit sizes and relative locations. Specifications and drawings shall include detailed requirements of the grounding system. A reference only to the National Electrical Code, without elaboration, has proven to be insufficient. Specifying requirements only by referencing the code is prohibited. It is required that the Associate shall specify all requirements applicable, instead of referring only to National Electrical Code. This includes specifying the size and requirement of all electrode ground conductors used for connecting to the ground rounds, electrode grounds in the concrete, cold water pipe and between the neutral and the equipment ground. It also includes sizing all equipment ground conductors routed with the phase conductors. All sensitive electronic equipment (computer rooms, etc.) shall have single point grounding system originating at the service entrance ground.
2. All connections to the grounding system shall be exothermic welded, cad weld or equivalent. It is required that the grounding system be tested and have a resistance reading of less than 5 ohms at the ground level. Only copper to copper may be clamped. The Associate shall calculate the system required to obtain 5 ohms. The contractor shall only be required to install the indicated system.
3. Service Ground: Grounding rods shall be a minimum size of 5/8" x 10' copper clad steel and shall not be placed in backfill. It shall meet current NEC requirements and other applicable codes.
  - a. Interconnection of the service ground, system neutral, and equipment ground conductors shall be made within the service equipment.
  - b. Grounding path through feeder conduits must be kept at less than five ohms resistance. The entire feeder conduit shall include a grounding conductor. The equipment enclosure (transformer case, etc.) shall not be used as a grounding path.
  - c. Grounding conductors shall be 600-volt insulated installed in rigid PVC where routed exposed. No metal parts such, as locknuts shall surround the ground conductor. If metal is used, protective conduits for ground conductors shall be bonded at both ends to reduce impedance in the ground path under fault current flow.
  - d. Lightning Protection: It is well documented that insulation levels of overhead lines is considerably higher than insulation levels of terminal apparatus including transformers, switchgears, pothead, etc. which make up or comprise the service entrance to buildings. Such overhead lines are vulnerable to overvoltage, mostly from direct or indirect lightning voltages and switching surges. It is a fundamental characteristic of the traveling voltage waves to increase in voltage when they arrive at equipment having a surge impedance higher than that of incoming line and the magnitude of such incoming waves will

approximately double at breaker. Therefore, this standard requires that all equipment connected by cable to overhead circuits shall have lightning/surge arrester protection at each end of the cable to guard against the possibility of transient over voltages. It is of great importance that protection against direct strokes is provided at outdoor substation installations in the form of grounded masts or overhead ground wires stretched above the installation to intercept lightning strikes, which might otherwise terminate on the lines or apparatus. It is also required that entrance equipment such as transformers, circuit breakers, etc. be protected against direct stroke from traveling waves by installing lightning arresters that possess protective characteristics below the impulse insulation strength of the terminal apparatus.

- i. This standard requires that lightning/surge arresters be installed as close as possible to the HV/MV terminals of the power transformer and all other equipment requiring surge protection be grouped as close as possible to the arresters. Use the station type arrester for the best protective level and highest surge discharge ability for important and critical installations. But the intermediate class type arrester shall be used for less critical installations and mostly for feeder protection.
  - ii. Protection of Power Stations and Substations: The protection of power stations (EMU electric stations) and substations (Coral substations) shall include the protection of station equipment by means of surge arresters of the type described in paragraph i of this section. These arresters should be mounted on, or closely connected to, the frames of the principal equipment which is being protected, especially transformers. It is also permissible to mount them on the steel frame work of the station or substation where all components are closely interconnected by means of grounding grid.
  - iii. This standard requires the following additional protective measures:
    1. Substation grounding network resistance shall not exceed 5 ohms. Lower values are preferred.
    2. Ground Conductors: The surge arrester grounding conductor shall be connected into the common station ground bus. The grounding conductor shall be run as directly as possible between the arresters and ground and be of low impedance and ample current carrying capacity. These requirements must comply with National Electrical Code.
    3. Indoor Locations: Arresters that are installed inside the buildings shall be enclosed or shall be located well away from passageways and combustible parts.
    4. Installation: This standard requires that arresters must be located and installed in such a manner that the expulsion of gales or the arrester disconnect is not directed upon energized parts.
    5. All protective lightning rods used for building or facility protection must have a master label pasted on them.
4. Transformer Grounds:
    - a. Building Service Transformers: Secondary neutrals shall be grounded separately from the neutral ground at the service main, unless close coupled in unit substation construction.
    - b. Low Voltage Transformers: Secondary neutrals shall be grounded in the low-voltage service equipment, as required by NEC for services.
  5. Equipment Grounds: A wire equipment ground shall be installed within the branch circuit conduit and be grounded to the cabinet of the panel board to an uninsulated ground bus. The neutral bar of the panel shall not be used for equipment grounds.
    - a. Equipment grounds and the identified neutral shall not be electrically interconnected on the building side of the service ground.
  6. Convenience Outlets: Specify that a wired ground be provided for continuity of ground path from the device-grounding pole. Provide ground fault interrupter outlets in wet conditions and where required by NEC and other related codes.

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7. Exterior Lighting Pole: For steel-framed structure, provide a concrete-encased reinforcing bar electrode. A steel rod similar to the reinforcing bar shall be used to join, by welding, a main vertical reinforcing bar to an anchor bolt. The bolt shall be permanently connected to the base plate of the steel column supported on that footing. The lightning protection ground system may then be connected by thermite weld or by a bronze bolt tapped into a structural member of that frame. An alternate method is to drive in 5/8" x 12'-0" ground rod adjacent the pole base and connect the ground rod to the base plate via a #2 ANG with all connections being thermite welds. All underground PVC conduits to the light poles shall contain a dedicated equipment ground copper wire. It shall be designed to provide a safe method of protecting electric distribution systems by causing the overcurrent or ground fault protective equipment to disconnect the circuit in case of ground fault.

\*\*END OF SECTION\*\*