READ THIS FIRST

Notice to the Design Engineer, please refer to the Port of Seattle, Facilities and Infrastructure standards for reference before editing this specification.

This Project Spec Document may need additional modifications to suit your project. It is recommended that you proofread each section, paying attention to any “Notes” boxes such as this one--you should remove these “Notes” sections as you go. Also, do a search for all bracket characters “ [ ] “ as they are used to show you areas containing options or project specific details (you can use Microsoft Word’s Find feature {Ctrl-F} to jump to an open bracket “ [ “ character quickly). Again, these bracket characters should be removed.

It is important that every paragraph be numbered to allow for easy referencing. If you use the document’s built in styles and formatting your outline should be fine (turn on the formatting toolbar by going to View > Toolbars > Formatting). Most paragraphs will use the style “Numbered Material” and can be promoted (Shift) or demoted (Shift-Tab).

You should not have to manually enter extra spaces, carriage returns or outline characters such as A, B, C, or 1.01, 1.02; the formatting will do this for you. The entire document is 11 pt. Arial. If you paste items in, you may need to reapply the “Numbered Material” format.

1. GENERAL
   1. SUMMARY OF WORK
      1. The extent and location of “Grounding and Bonding for Electrical Systems” Work is shown in the Contract Documents. 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.
   2. GOVERNING CODES, STANDARDS AND REFERENCES
      1. American Welding Society (AWS)
         1. AWS A3.0 - Standard Welding Terms and Definitions
         2. AWS A5.8 - Specification for Filler Metals for Brazing and Braze Welding
         3. AWS B2.1 - Specification for Welding Procedure and Performance Qualification
      2. American Society for Testing and Materials (ASTM)
         1. B3 - Standard Specification for Soft or Annealed Copper Wire.
         2. B8 - Standard Specification for Concentric-Lay-Stranded Copper conductors, Hard, Medium-Hard, or Soft.
         3. B187 - Standard Specification for Copper, Bus Bar, Rod and Shapes and General Purpose Rod, Bar and Shapes.
      3. Institute of Electrical and Electronics Engineers (IEEE)
         1. IEEE 81 - Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
         2. IEEE C2 - National Electrical Safety Code.
      4. National Electrical Manufacturers Association (NEMA)
         1. ANSI/NEMA GR 1 – Grounding Rod Electrodes and Grounding Rod Electrode Couplings.
      5. National Fire Protection Association (NFPA) -
         1. NFPA 70 National Electrical Code.
         2. ANSI/NFPA 780 - Standard for the Installation of Lightning Protection Systems.
      6. MIL-STD-889 Dissimilar Metals
      7. Underwriters Laboratories (UL)
         1. UL 467 - UL Standard for Safety Grounding and Bonding Equipment
         2. UL 546 – UL Outline of Investigation for Conductor Termination Compounds
         3. ANSI/UL 96 - Lightning Protection Components.
         4. ANSI/UL 467 - Grounding and Bonding Equipment.
   3. SUBMITTALS
      1. Submit materials data in accordance with of Section 01 33 00 - Submittals. Furnish manufacturers’ technical literature, standard details, product specifications, calibration reports, and installation instructions for all products.
      2. Submittals shall include the following:
         1. Submit product data for the following:
            1. Grounding conductors and cables.
            2. Grounding connectors.
            3. Grounding electrodes.
            4. Ground bus.
            5. Test wells.
            6. Exothermic weld kit.
         2. Grounding plans and calculations for Contractor’s designed ground system.
         3. Submittal log of locations where Contractor will bond grounding conductors to structural steel.
         4. Field Test Reports: Submit written test reports to include the following:
            1. Test procedures used.
            2. Test Equipment product data and calibration certification
            3. Test results that comply with requirements.
            4. Results of failed tests and corrective action taken to achieve test results that comply with requirements.
            5. Soil types and conditions where ground tests were performed.
         5. As-Built Data: Plans showing dimensioned as-built locations of grounding features specified in "Field Quality Control" Article, including the following:
            1. Test wells.
            2. Ground rods.
            3. Ground rings.
            4. Grounding arrangements and connections for separately derived systems.
   4. QUALITY ASSURANCE
      1. Listing and Labeling: Provide electrical components, devices, and accessories that are Listed and Labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to the Authority Having Jurisdiction, and marked for specific types, sizes, and combinations of conductors and connected items.
      2. Testing Agency Qualifications: Member company of NETA or an NRTL.
         1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.
      3. Comply with IEEE 837 and UL 467.
      4. Comply with IEEE Std. 142 (Green Book).
      5. Comply with NFPA 70.
      6. Comply with IEEE C2 for overhead-line construction and medium-voltage underground construction.
      7. Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system.
2. PRODUCTS

A. If only one product is acceptable (single or sole source product), obtain an approved Competition Waiver and submit to the CPO Construction, Contract Administrator. The language shall read as: “Manufacturer Name, Product # XXXXX, No Equal.” Refer to CPO-6 Competition Waiver Policy for more information.

B. If a Competition Waiver is not approved or more than one product is acceptable, this section must list a minimum of 2 products plus the language “Or Approved Equal,” along with salient characteristics. Refer to CPO Construction’s Salient Characteristics Guidelines for more information.

* 1. MANUFACTURERS
     1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
        1. Grounding Conductor Fittings:
           1. nVent Erico
           2. Chance/Hubbell.
           3. Copperweld.
           4. Burndy Electrical; Division of Hubbell.
           5. Ideal Industries, Inc.
           6. ILSCO.
           7. Kearney/Cooper Power Systems.
           8. Lyncole XIT Grounding; Division of VFC.
           9. O-Z/Gedney Co.
           10. Raco; Division of Hubbell.
           11. Thomas & Betts, Electrical; Division of ABB.
           12. Or Approved Equal.
        2. Grounding Connectors and Rods:
           1. Harger
           2. Galvan Electrical
           3. nVent Erico.
           4. ILSCO.
           5. Lyncole XIT Grounding; Division of VFC.
           6. O-Z/Gedney.
           7. Raco, Inc.; Division of Hubbell.
           8. Thomas & Betts; Division of ABB.
           9. Or Approved Equal.
        3. Ground Bars
           1. Harger GBI series.
           2. Erico EGBA series.
           3. Or Approved Equal.
  2. GROUNDING CONDUCTORS
     1. For insulated conductors, comply with Section 26 05 19 - 600 Volt or Less Wire and Cable.
     2. Material: Stranded Copper. ASTM B 8
     3. Equipment Grounding Conductors: Insulated with green-colored insulation in sizes available.
     4. 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.
     5. Grounding Electrode Conductors: Stranded cable.
     6. Underground Conductors: Bare, tinned, stranded, except as otherwise indicated.
     7. Bare Copper Conductors: Assembly of stranded conductors, ASTM B8.
     8. Copper Bonding Conductors:
        1. Bonding Conductor: #4 or #6 AWG, stranded copper conductor, sized per drawings.
        2. Bonding Jumper: Bare copper tape, braided bare copper conductors, terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.
        3. Provide two inch band of green plastic marking tape at each termination.
     9. Bonding Straps: Soft copper.
  3. CONNECTORS
     1. Listed and labeled by an NRTL acceptable to Authority Having Jurisdiction for applications in which used and for specific types, sizes, and combinations of conductors and other items connected.
     2. Exothermic Welds: Ensure the molds, materials and powder charges used to make exothermic welds are the standard product of a single manufacturer and listed by the manufacturer for use on the specific type, size, quantity and configuration of conductors to which the weld is applied.
     3. Irreversible Compression Lugs: Provide irreversible compression lug type connectors manufactured from tin-plated copper and installed using a hydraulic compression tool and die to apply correct, uniformly distributed, circumferential pressure. Ensure tools and dies are as recommended by the irreversible compression lug type connector manufacturer. Use an embossing die code or other standard method to provide visible indication that a connector has been adequately compressed onto the conductor. Apply irreversible compression lug type connectors in strict accordance with the manufacturer's written instructions and published installation instructions. Use 2-hole lug type connectors for connections to NEMA cable pads and bus bars, and single-hole connectors otherwise.
     4. Mechanical: Provide split bolt and clamp style mechanical type connectors manufactured from copper listed by the manufacturer as suitable for direct burial use. Ensure mechanical type connectors are applied in strict accordance with the manufacturer's published installation instructions.
     5. Bus-Bar Connectors: Mechanical type, cast silicon bronze, solderless compression-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.
  4. GROUNDING ELECTRODES
     1. Ground Rods: Solid copper clad steel, 3/4-inch diameter by 10-feet length.
     2. Plate Electrodes: Copper, 0.10 inch thick minimum.
  5. TEST WELL
     1. Provide test wells that are H2O rated, precast reinforced concrete, [circular][rectangular], with open bottom and concrete or cast iron lid/frame. Ensure test wells have inside dimensions of not less than [15 inches wide by 22 inches long][12 inches in diameter] by 24 inches deep. Provide test well lid with cast "GROUND" legend.
  6. GROUND BUS
     1. Ground bus: predrilled rectangular bars of annealed copper, 1/4 inch x 4 inches in cross section and 12” long with 9/32-inch holes spaced 1-1/8 inches apart arranged to allow for two-point termination of ground lugs. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V and shall be Lexan or PVC, impulse tested at 5000 V. Size and location as shown on drawings.

1. EXECUTION
   1. APPLICATION
      1. Comply with NEC Article 250
         1. Provide grounding system as required to obtain the resistance noted in NEC Article 250-56 as a minimum.
      2. Copper conductors for both insulated and bare grounding conductors in direct contact with earth, concrete, masonry, crushed stone and similar materials.
      3. In raceways, use insulated equipment grounding conductors.
      4. Exothermic-Welded Connections: Use for connections to structural steel and for underground connections.
      5. Irreversible Compression Lugs/Mechanical Connections: Use for exposed connections inside manholes and test wells.
      6. Equipment Grounding Conductor Terminations: Use bolted pressure clamps.
      7. Ground Rod Clamps at Manholes: Use bolted pressure clamps with at least two bolts.

Delete paragraph and subparagraphs below if grounding bus is not required, or edit to suit project

* + 1. Grounding Bus: Install in electrical equipment rooms, in rooms housing service equipment, and elsewhere as indicated.
       1. Use insulated spacer; space 1 inch from wall and support from wall 6 inches above finished floor, unless otherwise indicated.
    2. Underground Grounding Conductors: Install bare stranded copper conductor, size as indicated on drawings.
       1. Copper conductor, #2/0 AWG minimum. Bury per NEC minimum depth requirements or project drawings whichever is more stringent. .
       2. Ductbank Ground Conductors: Install a #4/0 AWG bare copper conductor embedded in concrete of each medium voltage ductbank. To avoid sag during install secure conductor to rebar cage. Provide a ground conductor with each medium voltage feeder circuit sized per the NEC.
  1. EQUIPMENT GROUNDING CONDUCTORS
     1. 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.
     2. Install equipment grounding conductors in raceways with all feeders and branch circuits unless otherwise noted.
     3. Provide an exterior personal safety ground bus bar on the back side of all medium voltage switchgear.
     4. 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.
     5. Isolated Grounding Receptacle Circuits: Install an insulated equipment grounding conductor connected to the receptacle grounding terminal.
        1. Isolate grounding conductor from raceway and from panelboard grounding terminals.
        2. Terminate at equipment grounding conductor terminal of the applicable derived system or service.
     6. Nonmetallic Raceways: Install an equipment grounding conductor in nonmetallic raceways unless they are designated for data cables.
     7. Air-Duct Equipment Circuits: Install an insulated equipment grounding conductor to duct-mounted electrical devices operating at 120V and higher, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment. Bond conductor to each unit and to air duct and connected metallic piping.
     8. Water Heater, Heat-Tracing, and Anti-frost Heating Cables: Install a separate insulated equipment grounding conductor to each electric water heater, heat-tracing, and anti-frost heating cable. Bond conductor to heater units, piping, connected equipment, and components.
     9. Signal and Communication Systems: For alarm, voice and data, and other communication systems, provide #4 AWG minimum insulated grounding conductor in raceway from grounding electrode system to each service location, terminal cabinet, wiring closet, cable try and central equipment location. All segments of cable tray shall be bonded together with ground conductor or flexible ground straps.
        1. Service and Central Equipment Locations and Wiring Closets: Terminate grounding conductor on a 1/4 inch x 4 inch x 12 inch grounding bus.
        2. Terminal Cabinets: Terminate grounding conductor on cabinet grounding terminal.
     10. Metal Poles Supporting Outdoor Lighting Fixtures: Provide a grounding electrode in addition to installing a separate insulated equipment grounding conductor with supply branch-circuit conductors. Reference Section 26 56 00 - Exterior Lighting.

If connections specified in paragraph below circumvent dielectric fittings intended to isolate interior piping systems from ground, other action may be necessary to prevent electrolytic corrosion.

* + 1. Common Ground Bonding with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lighting protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor, and install in conduit.
  1. BUILDING PERIMETER GROUND
     1. Ground the steel framework of buildings with a driven ground rod at the base of every corner column and at intermediate exterior columns at distances not more than 60 feet apart, or not to exceed 10 ohms.
     2. Provide a perimeter grounding conductor (counterpoise), electrically connected to each ground rod and to each steel column, extending around the perimeter of the building. Bury counterpoise per current NEC requirements or 30 inches below grade and 24 inches from building foundation whichever is more stringent. Install tinned-copper conductor not less than No.2/0AWG for ground ring and for taps to building steel.
  2. INSTALLATION
     1. Ground Rods: Drive ground rods until tops are 2 inches below finished floor or final grade. Interconnect ground rods with grounding electrode conductors. Use exothermic welds, except as otherwise indicated. Make connections without exposing steel or damaging copper coating.
     2. Grounding Conductors: Route along shortest and straightest paths possible. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.
     3. Bonding Straps and Jumpers: Install so vibration by equipment mounted on vibration isolation hangers and supports is not transmitted to rigidly mounted equipment.
        1. Use exothermic-welded connectors for outdoor locations, unless a disconnect-type connection is required; then, use a bolted clamp.
        2. Bond straps directly to the basic structure taking care not to penetrate any adjacent parts.
        3. Install straps only in locations accessible for maintenance.

Remove following paragraphs if not applicable

* + 1. 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.
       1. Connect grounding conductors to main metal water service pipes by grounding clamp connectors.
       2. Where a dielectric main water fitting is installed, connect grounding conductor to street side of fitting.
       3. Bond metal grounding conductor conduit or sleeve to conductor at each end.
    2. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with grounding clamp connectors.
    3. Gas Piping: Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.

Compare following paragraph with drawing detail for Test Well installation. Verify and update according to project parameters.

* + 1. Test Wells: Drive ground rod through drilled hole in the bottom of the handhole. Ground rod shall be at a minimum 12” deep. Connection to ground rod shall be made with a mechanical type connector. [Install one test well for each service at the ground rod electrically closest to the service entrance.][Install one test well for each equipment/pad ground loop][Install as shown in the contract drawings] Set top of well flush with finished grade or floor.
    2. Metallic Fence and Railing: Comply with the requirements of IEEE C2, current edition.
       1. Comply with details shown on the contract drawings.
       2. Metal fences around electrical equipment shall be bonded to the ground system with touch potential compliant with NESC.
       3. Grounding conductor shall be bare copper not less than 8 AWG.
       4. Gates shall be bonded to grounding conductor with flexible bonding jumper.
       5. Barbed wire shall be bonded to the grounding conductor.
    3. Bollards: Bond bollards to ground system per details shown on the contract drawings.
  1. CONNECTIONS
     1. 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.
        6. Tighten screws and bolts for grounding and bonding connectors and terminals according to manufacturer’s published torque-tightening values.
     2. Exothermic-Welded Connections: Weld using the exothermic process with procedures conforming to AWS A3.0M/A3.0, AWS B2.1/B2.1M, and manufacturer's recommendation. Where dissimilar metals are to be joined via exothermic weld, follow the weld kit manufacturer's recommendations and published instructions. Ensure connections between dissimilar metals do not produce galvanic action in accordance with MIL-STD-889. Use welding processes of the exothermic fusion type that makes a connection without corroding or loosening. Ensure process joins all strands and does not cause the parts to be damaged or weakened. Completed connection or joint is equal or larger in size than the conductors joined and has the same current-carrying capacity as the largest conductor
     3. 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 the grounding conductor.
     4. 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.
     5. Equipment Grounding Conductor Terminations: For #8 AWG and larger, use pressure-type grounding lugs. #10 AWG and smaller grounding conductors may be terminated with winged pressure-type connectors.
     6. Non-contact Metal Raceway Terminations: If metallic raceways terminate at metal housings without mechanical and electrical connection to housing, terminate each conduit with a grounding bushing. Provide flexible grounding strap mounted to raceway exterior where raceway crosses a seismic joint.
        1. Connect grounding bushings with a bare grounding conductor to grounding bus or terminal in housing.
        2. Bond electrically non-continuous conduits at entrances and exits with grounding bushings and bare grounding conductors, unless otherwise indicated.
     7. Connections at Ground Rods
        1. Exposed: Mechanical Type Connection
        2. Buried: Exothermic Welded Connection
     8. Connections at Test Wells: Use compression-type connectors on conductors and make bolted- and clamped-type connections between conductors and ground rods.
  2. UNDERGROUND DISTRIBUTION SYSTEM GROUNDING
     1. Ductbanks: Install a #4/0 AWG bare copper system grounding conductor embedded in the concrete of each medium-voltage ductbank. To avoid sagging during concrete pour, tie copper ground conductor to rebar with wire ties.
        1. Provide a ground conductor with each medium-voltage feeder circuit sized per NEC.
     2. Ground Vaults, Manholes, Handholes and Pull boxes in accordance with Section 26 05 43 - Underground Ducts and Raceways for Electrical Systems.
        1. 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, non-shrink grout.
     3. Connections to Vault and Manhole Components: Connect all exposed-metal parts, such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or vault to ground loop conductors.
        1. Make connections with #2 AWG minimum, stranded, hard-drawn copper conductor.
        2. Train conductors level or plumb around corners and fasten to vault or manhole walls.
        3. Make connection to cable shield as recommended by manufacturer of splicing and termination kits.
        4. Connect continuous ground cable in duct bank and equipment grounding conductor in each conduit to ground loop.
     4. Pad-Mounted Transformers and Equipment: Install four ground rods and Ground Ring circling pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with substations by connecting them to underground cable and grounding electrodes. Install copper conductor not less than #2 AWG for counterpoise and for taps to equipment ground pad. Bury counterpoise not less than NEC minimum distance below grade and 6 inches from the foundation.
  3. IDENTIFICATION
     1. Identify grounding system components as required by the Authority Having Jurisdiction and as specified in Section 26 05 53 - Electrical Identification.
  4. FIELD QUALITY CONTROL
     1. All ground system tests shall be performed in the presence of the Engineer.
     2. Test and inspect grounding systems in accordance with NETA Standard ATS, Section 7.13.

For Projects with planned construction during rainy season or areas with a high water table modify the paragraph below. Add additional testing requirements with grounding tests no fewer than [3] weeks after the first test meeting required values to confirm grounding system is meeting requirements.

* + 1. Measure ground resistance no fewer than two full days after 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.
    2. Test Requirements:
       1. Equipment Rated 500 kVA and Less: 10 ohms.
       2. Equipment Rated 500 to 1000 kVA: 5 ohms.
       3. Equipment Rated More Than 1000 kVA: 2 ohms.
       4. Power Distribution Units or Panelboards Serving Electronic Equipment: 2 ohms.
       5. Substations, substation manholes, and Pad-Mounted Switching Equipment: 1 ohms.
       6. Manhole Grounds: 10 ohms.
    3. Excessive Ground Resistance: If resistance to ground exceeds specified values at any single ground location and as a collective ground system, notify Engineer promptly and include recommendations to reduce ground resistance.
       1. Record test results. Provide bi-weekly Ground Resistance Test Report results to Engineer.
    4. Provide drawings locating each ground rod and ground rod assembly and other grounding electrodes.
       1. Identify each ground rod by letter in alphabetical order, and key to the record of tests and observations.
       2. 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.

1. MEASUREMENT AND PAYMENT
   1. GENERAL
      1. No separate measurement or payment will be made for the Work required by this section. The cost for this portion of the Work will be considered incidental to, and included in the payments made for the applicable bid items in the [Schedule of Unit Prices] [Lump Sum price bid for the Project].

End of Section

Revision History:

05/01/2014 Conversion to 2004 CSI Numbering System

10/15/2014 Added Sole Source and Salient Characteristics Note to Part 2 and revisions

09/27/2019 Revised Per F&I Standards

02/08/2021 Revised Per Code Updates, Changed Specification Title