Appendix E: Electrical - Additional Information

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Introduction

This appendix contains some additional electrical information, covering the following topics:

1. Appendix E-1 contains a list of items commonly overlooked by Contractors, complete with a few illustrations.
2. Appendix E-2 contains definitions and descriptions of various electrical conduits that may be encountered on a building project.
3. Appendix E-3 contains descriptions of various enclosures per the National Electrical Manufacturers Association.
4. Appendix E-4 contains information on the topic of grounding.

Appendix E-1 Items Commonly Overlooked by Contractors

It is the Contractor's responsibility to read all parts of the specifications and plans prior to beginning the installation of the electrical system. Below is a partial list of items that are commonly missed by the Contractor during construction. This list in no way implies that other parts of the plans or specifications will not be enforceable or applicable:

1. All equipment required to be submitted must be approved before installation. Any specified operation and maintenance manuals must be submitted and approved before completion of the contract.
2. Install all underground conduits at the depth specified in the specifications under “Sitework” or as shown on the plans.
3. All conduits terminated inside underground pull boxes must be brought up to at least 45 degrees above horizontal with the top set 2 inches above the pull box floor set away from the drain hole, 2 inches from the wall of its run. Splices of conductors must be made watertight. Pull boxes must be installed as specified and as shown on the contract plans or as shown in the Standard Plans.
4. Apply duct seal to all conduits within pull boxes and clean out all debris.
5. Ensure correct labels/markings on pull box lids (sometimes temporary lids with incorrect markings or labels are used)
6. Ensure proper fiber-optic or wire slack follows *Standard Specifications*/project plans
7. Locating and mapping post-installation as required per standard specifications, meaning obtaining CAD files showing all previously unknown underground facilities.
8. All method B splices must have Scotch-Clad coating applied.
9. Proper nameplates and labels.
10. All underground conduits changing to above-ground conduits inside a building must transition to rigid steel conduit prior to entering the building.
11. All conduits, regardless of their type, must have conduit bushings installed prior to pulling conductors. See Figure E-1.1.



Figure E-1.1. Metallic Grounding Bushing with a Plastic Throat and Double Locknuts

12. All exposed conduits inside the building below the switch height must be rigid steel conduit.
13. Exposed electrical metallic tubing may only be used inside buildings above the switch height.
14. All exposed outlet, device, and junction boxes installed below the switch height must be cast metal boxes.
15. Flexible metal conduit (minimum diameter 1/2 inch) is to be used only for connecting motors and for recessed lighting fixtures in lengths less than 6 feet. Other locations should only be allowed with the engineer's approval.
16. A pull rope must be installed in each empty conduit.
17. Use only specified fasteners to support equipment and conduits on surfaces. Refer to the specifications for approved fasteners.
18. Use only specified type connectors and fittings for all conduit terminations. Refer to the specifications for approved types of fittings and connectors.
19. Rigid conduits must be securely supported every 10 feet and within 3 feet of each enclosure, outlet, junction, and device box.
20. Conduit clamp back spacers shall be installed for all exposed conduits in damp or wet locations; see Figure E-1.2.



Figure E-1.2. Conduit with Clamp Back Spacer and Clamp Back Spacer

21. Do not use a common neutral for multiple circuits; the plans are designed to have a separate neutral for each circuit.
22. Do not change the size, number, or approximate location of conduit homeruns as shown on the plans. No combining of circuits is allowed.
23. Identify all conductors with wire numbers by one of the specified methods and in each location (panelboard, junction box, gutter, etc.) as specified. If the heat-shrink tubing method is used, it must be appropriately sized for the conductor. See Figure E-1.3 for an illustration.

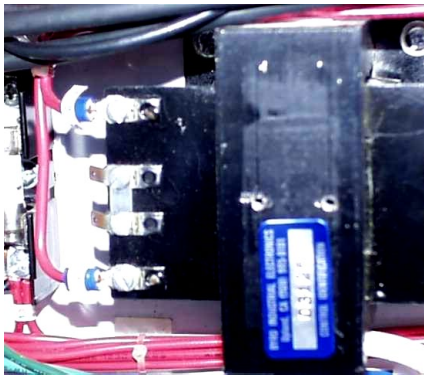


Figure E-1.3. Wrap-Around Identification Without Heat-Shrink Tubing That Leads to Peeling Identification

24. Use stranded copper conductors with correctly colored insulation. Refer to the specifications for the color coding required. All phase conductors AWG #8 and smaller shall have the proper colored insulation along their entire length.
25. Grounded conductors (neutral) AWG size #6 and smaller shall have white-colored insulation along their entire length.
26. Equipment grounding conductors AWG size #6 and smaller shall have green or green with yellow stripe colored insulation along their entire length, or be bare. **Insulated/Isolated grounds must have insulation.**

27. Power conductors installed in damp and wet locations (underground, etc.) shall be type XHHW-2.
28. All panelboard circuits should match the panel directories as shown on the plans. No changes are allowed except in a conflict. All panel directories (new and modified) shall be typewritten.
29. Install equipment with adequate working clearances in front of and around all electrical equipment.
30. Boxes mounted on combustible material shall be installed flush with the finished surface.
31. Rebar used for a ground bar must be uncoated, placed within 2 inches of the earth, and be a minimum of 20 feet in length.
32. Before finished walls and ceilings are constructed, the Contractor should notify the Engineer and arrange a rough-in electrical inspection from the design electrical engineer. The photo below (Figure E-1.4) shows when it is appropriate to have the electrical designer visit the site to inspect the conduit installation (pre-wall seal-up).



Figure E-1.4. Wall Section Ready for Electrical Rough-in Inspection

33. Nameplates are sometimes forgotten. Typically, panelboards and many electrical items have nameplates.
34. Warning signs are sometimes forgotten.
35. All project sheets need to be signed for "As-Built" changes, or stamped appropriately if there are no changes; see Attachment 3, *Guidance for Completing As-Built Project Plans*, of BCM C-6 for guidance.

Appendix E-2 Definitions of Electrical Conduit

RIGID STEEL CONDUIT is threaded conduit, hot-dip galvanized inside and outside. This is an extremely durable conduit that can take abuse. We call for threaded steel or malleable iron fittings to connect this conduit (not stamped steel fittings). This conduit has the same appearance and dimension as pipe, differing only in metallurgy and the smoothness of its inner surface. The metallurgy is designed to permit field bending without flattening of the cross section, and a smooth inner surface is required for low friction when pulling wire. This conduit is shipped in standard lengths of 10 feet, and each length must be marked with the Underwriters Laboratories (UL) marking and with the manufacturer's name or trademark; see Figure E-2.1 for illustration.

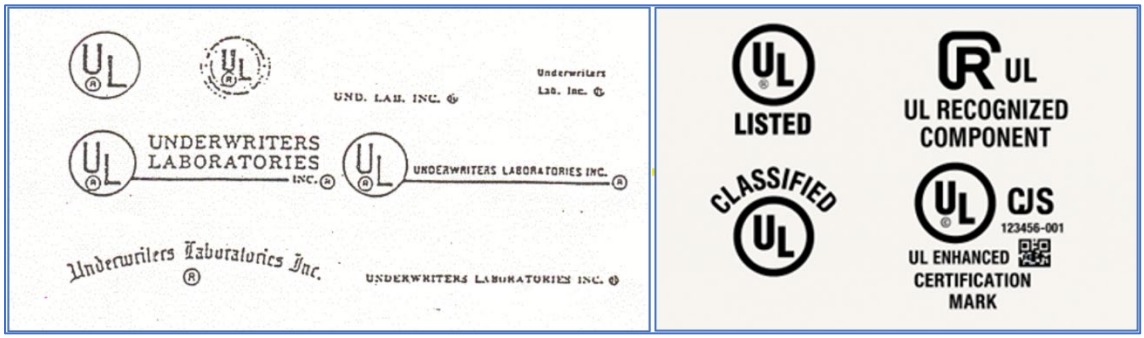


Figure E-2.1. Various UL Markings with Manufacturer's Trademark

COATED RIGID STEEL CONDUIT is hot-dip galvanized rigid steel conduit with fusion-bonded, 35-mils-thick-PVC coating on the exterior of the conduit. This conduit is shipped in standard lengths of 10 feet. This conduit should not be bent in the field, and standard factory-made couplings, elbows, unions, and hubs shall be utilized. Conduit shall be tightened into couplings or fittings using strap wrenches or approved groove joint pliers. Plastic-coated conduit couplings and conduit damaged by wrenches, groove joint pliers, threading machine chucks, or otherwise shall be wrapped with at least one layer of 2-inch-wide, 20-mil minimum thickness PVC tape conforming to ASTM designation D1000, with a minimum overlap of 1.2 inches.

HOT-DIP GALVANIZED INTERMEDIATE CONDUIT differs from rigid steel conduit only in wall thickness. It also is shipped in 10 - foot lengths, each marked with a UL marking, the manufacturer's name or trademark, and either the letters "IMC", the words "Intermediate Metallic Conduit", or the words "Intermediate Steel Conduit". **This material is seldom, if ever, specified for building work.**

ELECTRICAL METALLIC CONDUIT (EMT) has an enamel or lacquer coating on the inside and will be marked with the words "Electrical Metallic Tubing" in addition to the UL marking. The code does not specifically require the manufacturer's name on EMT.

PVC CONDUIT is shipped in 20-foot standard lengths and must be marked at least every 10 feet. In addition to the UL label and the manufacturer's identification, the marking shall include the words "Rigid Nonmetallic Conduit - Above Ground and Underground (Schedule 40)".

FLEXIBLE STEEL CONDUIT will have the UL label and the manufacturer's name on an attached tag, the reel, or on the container in which it is packaged, together with the words "Flexible Steel Conduit". Flexible metallic conduit must be fabricated in continuous lengths from galvanized steel strip, spirally wound and formed to provide an interlocking design.

LIQUID-TIGHT FLEXIBLE METAL CONDUIT is like flexible steel conduit except that it has an outer, liquid-tight, nonmetallic sunlight-resistant jacket. It will usually be marked with the code or UL. The marking may be on a tag, on the reel, or on the container. The marking will include the words, "Liquid-tight Flexible Metal Conduit" in addition to the UL marking and manufacturer's name.

Appendix E-3 National Electrical Manufacturers Association Descriptions

Many of the electrical boxes and panel enclosures will specify a National Electrical Manufacturers Association (NEMA) type rating. This appendix lists some of the common NEMA type enclosures.

NEMA TYPE	DESCRIPTION
Indoor Enclosures	
1	Enclosures are intended for indoor use primarily to provide a degree of protection against contact with the enclosed equipment or locations where unusual service conditions do not exist.
12	Enclosures are intended for use primarily to provide a degree of protection against dust, falling dirt, and dripping noncorrosive liquids.
12K	Enclosures with knockouts are intended for indoor use primarily to provide a degree of protection against dust, falling dirt, and dripping noncorrosive liquids.
13	Enclosures are intended for indoor use primarily to provide a degree of protection against dust, spraying of water, oil, and noncorrosive coolant.
9	Enclosures are intended for use in indoor locations classified as Class II, Groups E or G, defined in the National Electrical Code.
Outdoor Enclosures	
4	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, and hose-directed water; undamaged by the formation of ice on the enclosure.
4X	Enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water and hose-directed water; undamaged by the formation of ice on the enclosure.
3R	Enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet; undamaged by the formation of ice on the enclosure.

3	Enclosures are intended for outdoor use primarily to provide a degree of protection against windblown dust, rain, and sleet; undamaged by the formation of ice on the enclosure.
6	Enclosures are intended for use indoors or outdoors where occasional submersion is encountered, limited depth; undamaged by formation of ice on the enclosure.

Appendix E-4 Electrical Grounding

All electrical equipment must be grounded. This is accomplished by ensuring a continuous metallic path from the equipment back to the main serving switch enclosure. The grounding path will generally be provided by the main metallic conduit in which the conductor serving the equipment is installed. Some exceptions are:

1. Nonmetallic conduit must contain an equipment grounding conductor in addition to the circuit conductors.
2. Bonding jumpers must connect all ends of conduit stubbed into concrete or other underground pull boxes.
3. Conduits stubbed up inside metallic light poles must be bonded to the pole.
4. For flexible metal conduit, if the path contains more than 6 feet of it, or if the circuit is protected by an overcurrent device rated more than 20 amperes, the conduit must contain an equipment grounding conductor in addition to circuit conductors. The designer may require this grounding conductor even when the flexible metal conduit is shorter than 6 feet.
5. Flexible cables or cords supplying submersible sewage pumps, portable lamps, etc., must contain a separate equipment grounding conductor.

The minimum size of the equipment grounding conductors depends on the size of the circuit overcurrent device and is shown in Figure E-4.1 below.

E-4.01 Grounding Electrode System

The service to every building must have a grounding electrode system consisting of all of the following elements which exist: metal underground pipe (if 10 feet or more in length), metal frame of building, and concrete-encased electrode such as a rebar. If metal piping is the only one of these elements which exist, it must be supplemented by a ground rod. A ground rod alone may serve as the grounding electrode system only if none of the other elements named exist. The following list of notes applies to the grounding electrode system.

1. Grounding electrode conductor and all the bonding jumpers are to be enclosed in conduit regardless of their sizes.
2. Omit air line and/or water line if not present.
3. Omit building structural steel bonding if masonry block wall and/or wood construction.
4. Omit bonding underground water pipe nonmetallic and/or not present.

The size of conductor required to connect these elements together and to the main service switch depends upon the size of conductor feeding the building. For additional information, see Figures E-4.1 and E-4.2 below.

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	800
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4(A)(5) or (B)(4), the equipment grounding conductor shall be sized larger than given in this table.

*See Installation restrictions in 250.120

Figure E-4.1. Table NEC 250.122- Required Grounding Size Conductors

Grounding Electrode System Conductors for AC

Size of Largest Entrance Conductor or Equivalent Area for Parallel Conductors (Copper)	Size of Grounding Electrode Conductor (Copper)
2 or Smaller	8
1 or 1/0	6
2/0 or 3/0	4
Over 3/0 thru 350 kcmil	2
Over 350 kcmil thru 600 kcmil	1/0
Over 600 kcmil thru 1100 kcmil	2/0
Over 1100 kcmil	3/0

Figure E-4.2. Table NEC 250.66. Grounding Electrode System Conductors for AC

E-4.02 Bonding

The bonding details of the interior metal pipes to the grounding electrode system are usually shown as part of the building electric service or building disconnect. If not provided for in plan details or notes, the SR should contact the Electrical Designer for clarification. This contact should also be made when remodel projects utilize existing wiring, and the bonding system is not complete.

E-4.02A Bonding at Insulating Connections

Mechanical plans and specifications often provide for insulating unions and connections at specific piping locations. Division 15, *Mechanical Work* (SSP 99-15060, *Pipe, Fittings, and Valves*), also provides that these systems shall be bonded in accordance with NEC. Therefore, it is necessary that a bonding jumper be installed at all insulating connections unless otherwise specified.

E-4.02B Bonding at various Locations

Bonding jumpers are also required where conduit expansion couplings are installed. Grounding bushings and bonding jumpers are also necessary to ensure continuity where conduits terminate at concentric knockouts. In addition, NEC requires that grounding bushings and bonding jumpers be provided at all service conduit and conduit terminations inside service entrance equipment in each building or location.

Where multiple sets of service-entrance conductors are used, the equivalent size of the largest service-entrance conductor shall be determined by the largest sum of the areas of the corresponding conductors of each set. Contact your electrical designer for clarification.