Chapter 4-16: Electrical Work

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4-16.01 Work Included

The electrical work includes a vast array of elements, parts, and pieces. The electrical work will include grounding and bonding, conduit, enclosures, hangers and supports and their seismic bracing, identification of electrical systems and components, testing conductors and cables, raceways, boxes, cabinets, enclosures, wiring devices, utility services, motors and generators, battery powered and battery charger systems, static power converters, transformers, power measurement instrumentation, transmission and distribution accessories, line voltage and low voltage distribution, switchboards, panel boards, motor control centers, interior and exterior lighting, area lighting, emergency lighting, special purpose lighting, signal lighting, dimmer controls, lighting accessories, communications for both telephone data and radio, sound and perhaps video. The work will often include Information Technology (IT) conduits, data cables, and outlets. Recent projects have started to also include IT racks and server components in the construction contract. Prior to construction, confirm with Electrical Design and District IT to determine what work and equipment are to be supplied by the Contractor and what will be provided by District IT. District IT is responsible for making final connections to the State's network.

The Structure Representative (SR) is encouraged to meet with the electrical designer as soon as possible after they are assigned the building project. It is important to have the electrical designer review the work proposed and to provide guidance and direction to aid the SR in the inspection of the more complex and critical elements of the electrical work. Note that the terms "electrical engineer" and "electrical designer" may be used interchangeably in this chapter.

4-16.02 Tips and Suggestions to Prepare for Inspection of Electrical

1. Confirm the requirements and limitations of using rigid, thin wall, flexible, and plastic or nonmetallic conduit. Review the conditions where each type of material can be used, and confirm the specified material called for on the project plans. Conduit sizes and the number and type of conductors to be placed in the conduit should be observed for conformance with the contract requirements.
2. All conduits shall be reamed and cleaned of burrs and sharp edges before the installation of coupling connectors or fittings.
3. Assure that all couplers, connections, and fittings have the specified bushings to prevent damage to the insulation on the conductors and wires. Proper equipment shall be used to make conductor pulls. Observe the pulling of all conductors and cables to ensure the sheathing jackets or insulation of the materials are not damaged during the pulling operation.

4. Review the requirements for attaching and anchoring raceways and conduits to all the various elements of the structure, which may include: components of the trusses; structural frame members; surface mounted on concrete and masonry walls; and conduit installation within metal and framed walls and ceiling systems. Confirm the installations of underground conduits are at the designed elevation. Watch for any specified or required encasement, shading, or protection, and the requirement for any tracer tape. Sleeves shall be provided for the penetration of any wall or foundation.
5. Confirm the maximum bends and total degrees (angle) of bending allowed in any conduit run.
6. Confirm the proper setting depth of in-floor and under-floor raceways to ensure subsequent installations of junction boxes and devices will be correct. In-floor and under-floor raceways shall be properly supported and anchored to prevent movement during the placing of concrete.
7. The connection or junction of any conductors must be made in approved outlet boxes, receptacles, junction boxes, or devices. Connections are not allowed in the conduit runs.
8. Confirm and verify that the contract-specified color coding is being used on all wiring and that conductors are marked at their termination with the contract-specified identification markings. Site lighting and signal systems may refer to the standard specifications, in which there is specific color coding for the wiring.
9. Equipment grounding conductors are required in all non-metallic conduits. Typically, a ground conductor will also be included in metallic conduit. Equipment grounding conductors are to be securely attached to the equipment devices and other forms of the grounding system.
10. It is important to coordinate the layout and installation of all electrical work, such as conduits, devices, and receptacles, with the other pipe trades, architectural work, and structural work, to ensure their respective activities can be completed without conflicting with each other. Verify the location of all electrical equipment on concrete slabs and that the required conduit runs to the equipment are installed in or under the slab as specified and are in place before concrete is placed. Verify that conduit penetrations do not conflict with foundations and bearing walls. If conflicts are found, consult with structural and electrical designers for solutions that might involve enlarging foundations or changing the locations of the electrical penetrations. See Figure 4-16.1 for conduits penetrating a foundation.



Figure 4-16.1. Conduits Wrapped Where They Penetrate the Foundation

11. Structural elements cannot be bored, cut, notched, or otherwise modified without specific approval of the structural designer; refer to the “Framing Notes” on the “Structural Plans”, which may provide guidance on permissible size and locations of minor holes and notches.
12. Conduit layouts are diagrammatic; however, the locations of the devices, fixtures, switches, and receptacles are shown in the positions intended on the drawings.
13. Confirm the requirements for ground fault circuit interrupter (GFCI) circuits.
14. Confirm that wall receptacles, switches, outlets, and fixtures are installed at the height and locations shown in the project plans. Installation heights are typically fixed by codes and should not be changed without contacting the electrical engineer. Plaster rings or extension rings are required to provide a completely enclosed receptacle or box out to the surface of the wall finish.
15. Cover plates are required on all junction boxes. All junction boxes, wiring troughs, or other devices where junctions are made must be accessible. Verify any required access doors, in ceilings and walls are provided, to allow access to these locations.
16. Verify that all nameplates for identification ratings and other information remain intact on the motors and equipment, and are not painted over, covered, or otherwise obliterated. Confirm that the equipment is accessible for lubrication or maintenance.
17. Confirm that the designed disconnect switches are available and properly located with required clearance for each motor or motor starter and within sight of the motor or starter as seen in Figure 4-16.2.



Figure 4-16.2. AC Disconnect Switch

18. Confirm proper installation of control devices such as thermostats, pressure switches, and float controls.
19. Confirm that pads for such things as transformers, switchboards (or "switchgears"), and panel boards are located in the required location and of the size and configuration specified. All switches, panelboards, and other devices shall be rigidly anchored to the floor, walls, or other framing. Note that there is typically a working pad for personnel access in front of the switchgear with working height requirements; see Figure 4-16.37 for illustration.
20. Confirm that all circuits are provided as required in the project plans.
21. All lighting fixtures shall be placed as called for by the project plans (typically shown on the architectural sheet, reflected ceiling plan) and securely suspended, attached, or fastened to the structure in accordance with the authorized designs, submittals, and manufacturer's recommendations.
22. Lighting fixtures should be suitably protected during the course of construction and cleaned prior to final inspection and acceptance.
23. Confirm that fixtures in suspended ceiling systems are adequately supported and braced in accordance with the details in the project plans. Confirm that earthquake clips are installed in accordance with the contract documents. Confirm seismic wires are also sized in accordance with the contract documents.
24. Confirm that the raceways, conduits, boxes, and other devices required for communication and data systems are of the type and style and are installed in accordance with the contract documents.
25. All cabinet-installed equipment should be securely mounted and attached to the building systems. Plywood backboards are normally specified on which the cabinets and devices are to be mounted.
26. Fire and smoke alarm systems are to be installed by appropriate licensed technicians, and the installation and testing will be reviewed and approved by the State Fire Marshal. Final occupancy cannot be granted until such devices are

tested and approved by the State Fire Marshal. Confirm the proper location and performance of both audible and visual alarm devices.

27. Standby generators require special inspection and testing; confirm these requirements with the electrical designer. The State Fire Marshal will also have inspection, testing, and signage requirements for standby generators. Review the special provisions to determine whether the local air quality district has applicable requirements related to standby generators.
28. Ensure that all conduit cabling devices and other components are identified in accordance with the contract documents.
29. As mentioned in the introduction, it is recommended that the SR contact the electrical engineer soon after being assigned to the project, and enlist their assistance throughout the entire duration. The electrical engineer should not interact directly with the Contractor unless the SR is present.
30. Studying the project plans and special provisions, and calling the electrical engineer with questions, will help the SR develop familiarity with the electrical portion of the project.
31. The State Fire Marshal should be contacted early in the construction phase of the project if there is a Fire Marshal stamp on any of the plan sheets.
32. For electrical work, many installation details and requirements are covered in the special provisions.
33. By using phone calls, emails, and digital photos, you can keep your designer informed and obtain answers to questions that may arise.
34. Coordinate with designers to inspect the project at key times. It is recommended that, at a minimum, designers check the project during site work, before walls and ceilings are sealed up, and for the final inspection.
35. The following are items that have frequently been included on punch lists of past building projects.
    a. Conduit System:
        i. Depth of underground conduit is not per plans or project *Special Provisions*.
        ii. Conduit terminations are not per special provisions.
        iii. Type of conduit installed is not approved for the location.
        iv. Conduit home runs combined without concurrence of electrical engineer.
        v. Conduit support is not as required and specified.
        vi. Conduit bushings missing from conduits.
        vii. Pull rope is not installed in empty conduit.

b. Conductors:
   i. Common neutral is used for multiple circuits.
   ii. Conductor identification used is not per applicable specifications.
   iii. Conductor insulation color is not per applicable specifications.
   iv. Conductors in combined home runs are not de-rated.
c. Equipment:
   i. Equipment installed is not authorized by the Engineer.
   ii. Panel directories and circuit breaker arrangement do not match plans.
   iii. Working clearance in front of equipment is not per code.

4-16.03 Electrical Work

Division 16, *Electrical Work*, always starts with this section (SSP 99-16010), and it serves as the introduction and summary portion of the electrical work. Applicable codes, related work, closeout submittal requirements, and testing requirements are included in this section.

Review any Standard Special Provisions (SSP) from Section 99[1], *Building Construction*, Division 16, *Electrical Work*, that have been included in the project *Special Provisions*, since much of the information therein typically will not be repeated in the following sections of this chapter.

4-16.03A Applicable Codes

Numerous codes, regulations, and standards apply to the various portions of Division 16 work. The applicable code references are included in the “General” and “Quality Assurance” portions of the Division 16 subdivisions in the *Special Provisions*.

4-16.03B Submittals

Attention is directed to each section of Division 16 for specific requirements on items requiring submittals. For example, some items require wiring diagrams. Some systems require submittal to the utility company or the State Fire Marshal. All electrical equipment listed requires submittals either for authorization or for informational purposes. It is critical that submittals be started early in the project so they do not delay ordering and installing equipment. Some equipment, such as switchboards and generators, may have lead times of more than one year between the order and delivery of the equipment. The authorized submittals must be available to properly locate conduits for an electrical room, generator room, or similarly complex areas.

[1] Caltrans internal use only

4-16.03C Closeout Submittals

Closeout submittals include the requirement for providing electrical operation and maintenance manuals prior to contract completion. Electrical equipment requiring manuals is listed in this part of the special provisions and may include the following:

1. Standby generator
2. Intrusion alarm system
3. Fire alarm system
4. Well pump control panels
5. Sewage lift pump control panels
6. Communication systems.

These manuals are in addition to any product record drawings, parts lists, warranties, and product submittals that may also be required.

Operation and maintenance manuals may contain generic information that covers a range of similar products and models. If necessary, the Contractor will edit these manuals to provide the owner with the details applicable to the actual equipment installed.

The Contractor must note any changes made in the field on the as-built project plans submitted at the closeout phase of the project.

4-16.04 Basic Materials and Methods

This section of Division 16 (SSP 99-16050) includes basic electrical materials such as conduits, conductors, box fittings, and wiring devices. In the 50-section Construction Specifications Institute (CSI) format, you will find this repeated in the sections for each type of wiring or conductor system.

4-16.04A Conduits

Rigid steel conduit (RSC or MC), electrical metallic tubing (EMT or thin wall conduit), flexible metallic conduit, liquid tight flexible metallic conduit, rigid nonmetallic conduit (PVC), and PVC-coated (plastic coated) rigid steel conduit shall be installed as indicated in your project *Special Provisions*. Caltrans building jobs do not specify or allow the use of intermediate steel conduit. A description of the various conduits is included in Appendix E-2, *Definitions of Electrical Conduit*.



Figure 4-16.3. Stacked RSC Conduit



Figure 4-16.4. Liquid-Tight Flexible Metallic Conduit and Fittings

4-16.04A(1) Type

The general requirement is that all conduits shall be hot-dipped galvanized rigid steel conduits (Figure 4-16.3) unless otherwise shown on the plans or specified. EMT is permitted in furred spaces and for exposed conduit installation indoors above switch height. Exposed EMT installed below switch height is considered vulnerable to damage and therefore not used in these applications. Also, EMT is not allowed for underground or underfloor installations. In addition, the project *Special Provisions* requires that a short length of flexible metal conduit or liquid-tight flexible conduit (depending on whether indoors or outdoors) be used for the connection to motors or any equipment subject to vibration (Figure 4-16.4). Caltrans SSPs for building work do not allow flexible steel conduit in stud walls.

4-16.04A(2) Size

The size of each run of conduit is indicated on the project plans. All runs with size not specifically shown are to be a uniform size, which will be given in a note or in the legend (usually 1/2-inch).

4-16.04A(3) Cutting and Threading

Each 10-foot manufactured length of conduit has been reamed and threaded on both ends at the factory. All field cuts must also be reamed. Unreamed cut conduit will cause damage to the conductors during the conductor pulling process and may cause premature failure. Conduit ends threaded in the field must not have either too long or too short of the threaded portion. Conduit should be threaded just through the die plus or minus one thread. A thread cutting operation is shown in Figure 4-16.5.



Figure 4-16.5. Cutting Threads on Rigid Steel Conduit

4-16.04A(4) Connections to Boxes and Panelboards

All threaded connections must be wrench tight. Connectors for EMT, flexible conduit, and liquid-tight flexible conduit must conform to the special provisions and must be approved by the Underwriters Laboratory (UL) for the type of conduit on which they are used. UL approval will be indicated on the box in which the connectors are packaged.

Some connectors are approved by UL but are not allowed on Caltrans projects. Therefore, it is important that all connectors and couplings comply with the project *Special Provisions*. Caltrans specifications exceed the National Electrical Code (NEC) for conduit terminations. Therefore, refer to the special provisions for conduit terminations at junction boxes, panelboards, and at underground pull boxes. Figure 4-16.6 shows an EMT set screw fitting that is not allowed per applicable specifications, and Figure 4-16.7 shows a 3-piece compression coupling for EMT conduit, which is required by the specifications. Figure 4-16.8 shows a 3-piece compression coupling being installed on EMT conduit.

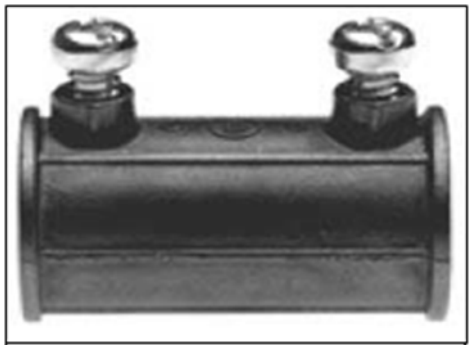


Figure 4-16.6. EMT Set Screw Fitting - Not Allowed per Specifications



Figure 4-16.7. 3-Piece Compression Coupling for EMT Conduit



Figure 4-16.8. Installing EMT Compression Coupling

4-16.04A(5) Routing

Conduit runs for which specified locations are not shown on the project plans are to be ran parallel or perpendicular to building lines, if exposed. See Figures 4-16.9 and 4-16.10 illustrating exposed conduit runs. Figure 4-16.11 shows conduit runs that will be enclosed in a wall or ceiling.



Figure 4-16.9. Exposed Conduit Runs



Figure 4-16.10. Exposed Conduit Runs in Maintenance Equipment Bay



Figure 4-16.11. Conduits in Ceiling and Wall

4-16.04A(6) Bends

Between pull points, no runs of conduit of any type may contain more than 360 degrees of total bends. Rigid non-metallic conduit (PVC) bends of 30 degrees or greater shall be factory-made long radius sweeps. PVC conduit bends less than 30 degrees shall be made using an approved heat box. PVC conduit must not be bent by using an open flame.

4-16.04A(7) Supports

All conduits must be securely fastened in place. For rigid steel conduits and electrical metallic tubing, the maximum distance between supports is 10 feet. For flexible conduits, the maximum distance between supports shall be 4½ feet, and the maximum distance from any box or any enclosure to the first support shall be 12 inches. See Figure 4-16.12 for conduit supports in a metal building, and Figure 4-16.13 for conduit supports on masonry walls.



Figure 4-16.12. Supports for Conduit Runs in Equipment Bay



Figure 4-16.13. Conduit Supports on Masonry Wall

4-16.04A(8) Home Run

A conduit home run is the conduit and conductors from devices back to the panelboard or control panel supplying the devices. Each line on the project electrical plans with a single or multiple arrows indicates a home run. The number of arrows on the home run conduit indicates the number of circuits fed by the home run.

The Contractor may propose combining home runs/circuits to save conduit length. This means that they will install conductors of more than one system in one home run. This situation gives rise to other complications relating to the National Electrical Code (NEC) and must **not** be allowed on any project. In addition, this practice greatly complicates future additions and system maintenance.

4-16.04A(9) Bushings

All conduit terminations shall be provided with bushings as follows:

1. Where a rigid steel conduit enters a pull box, junction box, or enclosure, a conduit bushing shall be installed prior to pulling of conductors. See Figures 4-16.14, 4-16.15, and 4-16.16 for some typical types of bushings.



Figure 4-16.14. Plastic Bushing for Conduit



Figure 4-16.15. Conduit Termination Fitting for RSC with Plastic Throat

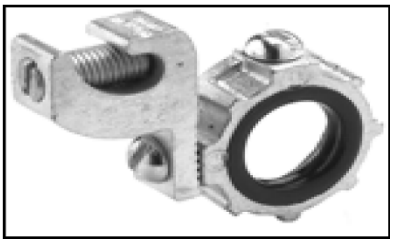


Figure 4-16.16. Ground Lug Bushing

2. Where a PVC conduit enters a pull box or a junction box (or enclosure within a salt storage building), an approved conduit bushing or adapter shall be installed prior to pulling the conductors.
3. EMT requires no separate bushings at boxes or enclosures because they are terminated with factory-made connectors with an insulated throat. Caltrans typically specifies that EMT fittings have an insulated plastic throat, which provides additional protection to conductors.

4-16.04A(10) Underground Conduit

Attention is directed to SSP 99-02220, *Earthwork for Building Work*, for the depth of conduits installed underground. Underground conduit should have a layer of sand bedding under the conduit and a layer of sand above the conduit, as shown in Figures 4-16.17 and 4-16.18. The specifications usually require a warning tracer tape to be placed 12 to 18 inches above the conduit with an inscription of “Warning” or “Caution - Buried Electric Line Below,” as seen in Figure 4-16.19.



Figure 4-16.17. Sand Base for Underground Conduits



Figure 4-16.18. Underground PVC Conduit with Sand Bedding



Figure 4-16.19. Underground Conduit Backfill with Warning Tracer Tape Installed Above the Conduits Showing Center of Trench

4-16.04A(11) Conduit Seals

Fuel island and sewage lift station installations require conduit seals to prevent flammable gases from migrating into and through the conduit system. Conduit seals shall be malleable iron body, threaded, sealable conduit fitting. The fitting shall come with fiber filler and UL-listed sealing cement. The fitting may or may not have a condensation drain. Filling and sealing of these fittings should be done with the concurrence of the electrical engineer, as once they are sealed, the wires cannot be removed. Keep in mind that the pictures below (Figures 4-16.20 and 4-16.21) are representative only, and installed items must match the authorized submittals. Figure 4-16.22 shows conduits installed with sealable fittings at a fuel island coming into a gutter with bushings and plastic throats for pulling wire.



Figure 4-16.20. Conduit Seal



Figure 4-16.21. Conduit Seal



Figure 4-16.22. Conduits and Gutter for Fuel Island Showing Conduit Seals and Bushings with Plastic Throats

4-16.04A(12) Conduit Above Suspended Ceilings

EMT is permitted above suspended ceilings. It is general industry practice to support this tubing, as well as outlet boxes feeding the light fixtures, by clipping to the galvanized wire hangers which support the T-bars, which in turn support the ceiling tiles and light fixtures. Conduit may be supported by clipping to these T-bar hangers of the suspended ceiling unless the special provisions specifically prohibit it. Figure 4-16.23 shows conduit above a suspended ceiling grid, supported by the metal ceiling joists and blocking.



Figure 4-16.23. Conduit Runs above a Suspended Ceiling

4-16.04A(13) Conduit Protection

Metal plates should be placed on wood studs where conduit passes through to protect them from damage from gypsum board screws or nails, as shown in Figure 4-16.24.



Figure 4-16.24. Conduit Protection Plates on Wood Studs

4-16.04B Conductors

Normally, four types of conductors, THWN, THHN, XHHW-2, and MTW are specified for building jobs, except in District 6 and 9, where Type TW or THW conductors (to protect against damage from ants) are specified. All conductors are suitable for installations in dry locations, but conductors with alpha character “W” in the conductors' designation indicate that the conductor is suitable for underground/wet installations. All conductors shall be rated for 600 volts. The conductor code gauge (size) is marked on the outer sheathing and can be easily read, as illustrated in Figure 4-16.25.

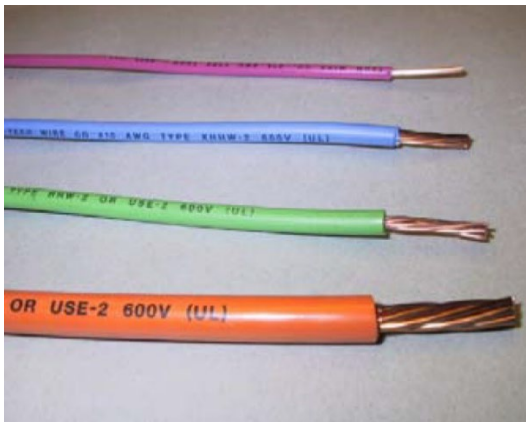


Figure 4-16.25. Conductors with Wire Size Noted

All conductors shall be stranded copper conductors unless otherwise specified.

For various types of conductors specified for your project, please refer to “Cables and Conductors” within SSP 99-16050, *Basic Materials and Methods*, of the special provisions.

4-16.04B(1) Conductor Color-Coding

The NEC and special provisions control the insulation color for conductors to be installed on your project. The NEC requires that the neutral and equipment grounding conductors (ground wires) shall be identified as follows:

1. Neutral conductors No. 6 and smaller shall have white or natural gray insulation. Neutral conductors No. 4 and larger shall be identified by distinctive white marking, such as paint or white tape, at each termination.
2. Equipment grounding (ground wire) conductors shall be bare or insulated. If insulated, conductors No. 6 and smaller shall have green or green with one or more yellow stripes insulation over their entire length. Conductors No. 4 and larger are permitted to be permanently identified by distinctive green markers, such as paint or green tape, over their entire exposed insulation.

All other conductors (feeder and branch circuit conductors) shall be identified with colored insulation as indicated in the project specifications. However, conductors larger than No.6 may be identified by distinctive colored markings at their terminations.

Control circuits and switch leg conductors may be colored with other colors or combinations for identification. The alternate colors must not conflict with other colors used or with the required neutral or ground colors.

4-16.04B(2) Conductor Identification

Identification of conductors with their circuit and panelboard number is important during troubleshooting when the building is in operation. Attention is directed to “Conductor Identification” within SSP 99-16050, *Basic Materials and Methods* for the type of identification materials that are approved, and the required locations where conductors shall be identified. Figure 4-16.26 below is a close-up view of a panelboard with the conductors identified with either temporary or in-process labels.

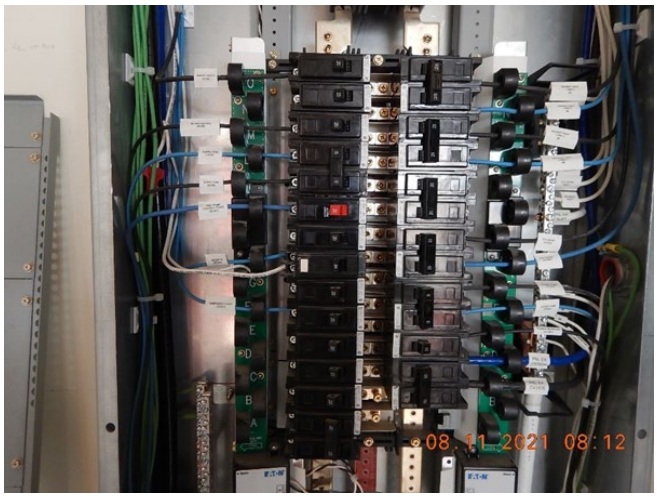


Figure 4-16.26. Close-up of Panelboard

Proper identification of conductors is time-consuming, and most contractors are not in the habit of doing it. Bringing the Contractor's attention to this issue early may save time and hassle in the long run.

4-16.04B(3) Separate or Combined Neutrals

Project plan details usually provide for a separate neutral for each branch circuit. In some cases, a common neutral is shown. To determine neutral configuration, it is necessary to review the number of conductors shown for the home run. Unless shown on the plans or directed by the electrical engineer, do **not** allow the use of a common neutral on your project.

It is imperative that the neutrals are not transposed in circuits with a switched neutral circuit breaker or a ground fault circuit interrupter (GFCI). GFCI breakers and GFCI feed-through outlets will trip whenever an alternate path is available to any load. When tripped, a switched neutral circuit breaker will interrupt power to equipment connected to either conductor. Check each circuit's operation when wiring is completed.

4-16.04B(4) Cables

Cables will be as specified in your project *Special Provisions*.

4-16.04C Boxes and Fittings

Junction boxes, device boxes, and covers will be marked with the UL marking, the manufacturer's name, and the appropriate product name. For fittings, which can be too small to label directly on the product, they must at minimum have the UL marking, the manufacturer's name, and the appropriate product name on the packaging (box, carton, or bag) they are packaged in.

All boxes, conduit bodies, covers, and extension rings shall be durable and legibly marked with the manufacturer's name or trademark. Metal boxes and fittings shall be corrosion resistant or shall be well galvanized, enameled, or otherwise coated inside and out to prevent corrosion. In wet locations, boxes and fittings shall be listed for use in wet locations.

4-16.04C(1) Box Types

The National Electrical Manufacturers Association (NEMA) provides standards for classification of boxes. Figure 4-16.27 and 4-16.28 illustrate two different types of electrical boxes.



Figure 4-16.27. Galvanized Junction Boxes for Stud Walls



Figure 4-16.28. Cast Weatherproof Metal Box

4-16.04C(2) Box Sizes

Junction and device (outlet, switch, etc.) boxes have size limitations per the NEC, which restrict the number of devices and conductors that may occur in a specific sized box. The 4-inch-square by 1-1/2-inch-deep boxes specified by Caltrans are satisfactory for the size and number of conductors normally involved. Problems can occur where several circuits are routed through a single box or when 2-inch by 3-inch by 1-1/2-inch-deep boxes are used for applications other than a light switch or duplex receptacle. If you notice any boxes that seem crowded, you should contact the electrical engineer, who can verify if the installation meets the requirements of the code.

Unused openings in boxes and fittings shall be effectively closed to afford protection substantially equivalent to that of the wall of the box or fitting.

4-16.04C(3) Boxes in Walls

In walls or ceilings of tile, concrete, or other non-combustible material, boxes and fittings shall be installed so that the front edge of the box or fittings will be flush with the finished surface. In walls or ceilings of combustible material, boxes and fittings shall be flush with the finished surface or may project from the surface in a surface-mounted condition.

4-16.04C(4) Boxes installed in Fire Resistant Walls

The Uniform Building Code (UBC) contains restrictions which relate to the penetration of the membrane of a fire-resistive wall. It is important that these limitations not be exceeded. The SR should watch for locations in fire-resistive walls where outlet boxes on opposite sides are planned near each other, or when a combination of switches or other devices may require an opening in the gypsum board sheeting in excess of 16 square inches. Fire-resistive walls and partitions may have openings for steel electrical outlet boxes not exceeding 16 square inches in area, provided the aggregate area of such openings is not more than 100 square inches for any 100 square feet of wall or partition area. A horizontal distance of not less than 24 inches shall separate outlet boxes on opposite sides of a wall or partition. If in question, discuss with the Project Architect and electrical engineer.

4-16.04C(5) Supports

Boxes shall be securely and rigidly fastened to the surface upon which they are mounted, or securely and rigidly embedded in concrete masonry. Where nails are used as a method of mounting and pass through the interior of the box, they shall be located within ¼ inch of the back or ends of the box. Boxes, other than as described below, shall be supported from a structural member of the building either directly, or by using an approved metal or wooden brace. If wood, the brace must be not less than 1 inch (nominal) thickness. If metal, it must be corrosion-resistant and shall be not less than No. 24 gauge. Figure 4-16.29 shows metal support straps for boxes in a steel stud wall.



Figure 4-16.29. Proper Supports for Junction Boxes in Steel Stud Wall

Threaded boxes or fittings not over 100 cubic inches in size that do not contain devices or support fixtures shall be considered adequately supported if two or more conduits are threaded into the box wrench-tight and are supported within 3 feet of the box on two or more sides.

Threaded boxes or fittings over 100 cubic inches in size which contain devices or support fixtures weighing 50 pounds or less shall be considered adequately supported if two or more conduits are threaded into the box wrench-tight, and are supported within 18 inches of the box.

4-16.04D Wiring Devices

Wiring devices include receptacle outlets and switches. The specific types of receptacle outlets and switches are shown on the plans and described in the special provisions.

4-16.05 Service and Distribution

This section of Division 16 includes service equipment such as service pedestals and main switchboards. This equipment shall have the approval of both the electrical engineer and the servicing utility company.

It is the contractor's responsibility to contact the utility company and arrange for the service. The SR should read the "Utility Connection" section under SSP 99-1, *General Requirements*, of the special provisions very carefully to see who pays for the service work. Because service connections can be very expensive, eliminating mistakes is highly recommended. Utility coordination can be time-consuming and can cause delays if it starts too late.

A utility company representative will typically inspect trenches and conduits prior to pulling in their cables. Utility companies usually have special requirements for their trenches. While not mentioned in the *Special Provisions* directly, service equipment shall have sealing material installed between the enclosure and the concrete pad to seal it (per the NEC requirements).

4-16.05A Panelboards

The panelboard circuit breaker layout must be the same as shown on the project plans, and each circuit should be checked to ensure that it corresponds to the authorized submittal. Each panelboard is to have a typewritten directory installed on the inside of the door, and it must match the layout. Figure 4-16.30 illustrates two panelboard enclosures mounted on plywood backing board. Figure 4-16.31 contains two panelboards with circuit breakers installed and partially wired up.

The circuit breaker rating is shown on the operating handle. Each circuit breaker should be checked to ensure that it corresponds to the rating shown on the authorized submittal. Figures 4-16.32, 4-16.33, and 4-16.34 illustrate various types of circuit breakers.

The project plans indicate when GFCI circuit breakers are required. These circuit breakers are furnished with a built-in test circuit. Each GFCI breaker should be tested by depressing the test button.

The contract documents will require that each circuit leading to, or through, a fuel-dispensing pump be provided with a switch or other acceptable means to interrupt all conductors of the circuit, including the neutral conductor. This is accomplished by providing a switched neutral circuit breaker.



Figure 4-16.30. Panelboard Enclosures on Plywood Backboard



Figure 4-16.31. Two Panelboards Partially Wired



Figure 4-16.32. GFCI Circuit Breaker

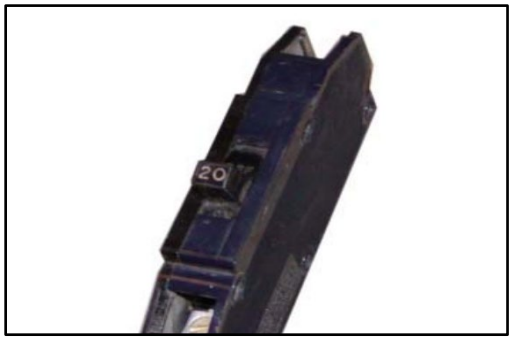


Figure 4-16.33. Single Pole, 20 Amp, Circuit Breaker



Figure 4-16.34. 3-Pole Circuit Breaker

If a panelboard is installed outdoors or at another location requiring a weatherproof enclosure, the conduits terminating at the panelboard must have weatherproof hubs.

4-16.05B Main Switchboards

The main switchboard is the location where the electric utility company will supply the power and have the meter for the facility. It will usually have sections for distribution of electricity to various panels in the facility. Figures 4-16.35 and 4-16.36 show photos of main switchboards (MSB). The servicing utility company will require a minimum distance level clear working space in front of the MSB. The utility should be contacted to determine what this distance is. Figure 4-16.37 shows a 4-foot level working surface, as was required by PG&E, in front of the MSB.



Figure 4-16.35. View of MSB with a Transformer Pad in Foreground



Figure 4-16.36. View of MSB with Exterior Doors Open



Figure 4-16.37. Level Pad Working Area in front of MSB

4-16.05C Transfer Switches

If there is a standby generator that will be connected to the power service, the MSB will have a transfer switch section with an automatic or manual transfer switch. This switches the power supply between the utility power and generator power, and is electrically set so that if connected to generator power, there is an open switch to prevent the generator power from backfeeding electricity into the utility company's equipment. Figures 4-16.38 and 4-16.39 show the exterior of an automatic transfer switch cabinet and the interior of this cabinet, which is connected to the main switchboard.



Figure 4-16.38. Automatic Transfer Switch Section of MSB

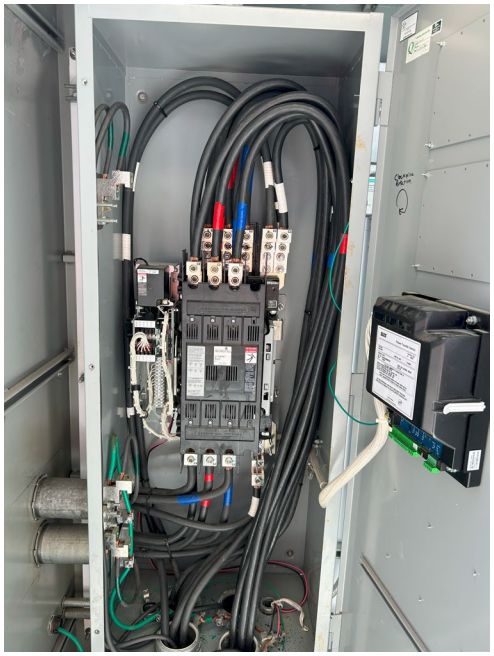


Figure 4-16.39. Interior of Automatic Transfer Switch Compartment

4-16.06 Electrical Equipment

The Division 16 SSP 99-16432, *Electrical Equipment*, includes electrical equipment such as panelboards, starters, disconnects, control panels, motor control centers, and other miscellaneous equipment. In some cases, control panels for systems like water control systems, sewage control systems, and weigh station systems are specified in a separate section.

4-16.06A Equipment

Full descriptions of the above-listed items will be in the special provisions and require authorized submittals before installation.

4-16.06B Location of Equipment

The location of all electrical equipment is indicated on the plans, and the equipment must be placed accordingly. If conditions require this location to be changed, the proposed change shall be reviewed and authorized by the electrical engineer.

The arrangement of equipment, terminals, the connections between them in control panels, and the layout of groups of equipment on walls are normally presented in considerable detail on the project plans. The project plans are an invaluable aid to subsequent maintenance and troubleshooting. The project plans shall be followed unless replacement drawings in equivalent detail have been submitted as shop details by the contractor and have been authorized and/or approved by the design team or authority having jurisdiction.

4-16.06C Workspace

All electrical equipment must be installed so that there is a clear standing space in front of it. This space should be as wide as the equipment or 30 inches wide, whichever is greater, and a minimum 6 ft 3 in high. The depth of this working space measured from the front edge of the enclosure shall never be less than 3 feet. For equipment with voltage of 277 or 480 V(ac), this depth must be increased to 3-1/2 feet if its limit is a concrete or block wall or a grounded metal object, and to 4 feet if its limit is other electrical equipment.

4-16.06D Mounting Height

Equipment mounting height will either be indicated on the project plans or in the special provisions. The maximum height that equipment with circuit breakers can be installed is such that the center of the circuit breaker's operating handle, when in its highest position, is not more than 6 ft 7 in above the floor or working platform; see Figure 4-16.40 for an illustration.



Figure 4-16.40. Panelboard Height to Top Circuit Breaker

4-16.06E Supporting Hardware

Supporting hardware and devices shall follow the guidelines contained in the special provisions.

4-16.06F Motor Starters and Overload Heaters

Motor starters differ from other switches or contactors in that they provide protection for the motor in addition to operating the motor.

Overload heaters provide motor protection. The electrical engineer will verify that the heaters have been properly sized during the final inspection.

4-16.06G Equipment Disconnects

All equipment and appliances with a rating over 300 volt-amperes (VA) must be provided with means to disconnect all ungrounded conductors. This disconnect must be located within sight of (a 50-foot maximum distance) and readily accessible from the equipment. Figure 4-16.41 is an example of equipment disconnects for air conditioning units.



Figure 4-16.41. Equipment Disconnects for A/C Units

4-16.06H Overcurrent Protection for Air Conditioners or other Devices

For air conditioners, the project plans will indicate the size of the overcurrent devices and the wire size required to suit the furnished equipment. The electrical engineer will check conductor and circuit breaker sizes during the submittal process. Any revisions needed will be noted in red. When the panelboard is delivered to the jobsite, verify that these red line comments have been addressed. Contact the electrical engineer if assistance is required. For HVAC items and other items specified in Division 15,

Mechanical Work, or on the “Mechanical Plan” sheets, verify that your electrical engineer has also reviewed the mechanical item submittal for any corresponding revisions that might be needed to the electrical portion of the item.

4-16.06I Control Panels and Systems

Control panels are used to control various items and systems such as HVAC, water supply, sewage, lighting control, and many other items that require control circuitry. These will usually be in some sort of enclosure or cabinet. They will require submittals for all the electronic parts that go inside them, as well as layouts and wiring diagrams for all parts. If control systems are present on the project, the control panel(s) should follow the installation and working clearance guidelines of SSP 99-16432, *Electrical Equipment*. An as-built wiring diagram will be required with close-out documents, and a copy is to be placed inside the control panel.

4-16.07 Lighting

The Division 16 SSP 99-16500, *Lighting*, includes the lighting fixtures, lighting control panels, lighting poles, and other equipment associated with the lighting system.

4-16.07A Lighting Fixtures

All lighting fixtures must be securely supported. Fixture locations shall follow the project plans, and for ceiling-mounted installations, the exact location is shown on the architectural reflected ceiling plan sheet. Installation shall follow the manufacturer’s recommendations included in the approved submittal. Fixtures installed outdoors, in enclosed maintenance station wash racks, or other potentially wet areas shall be marked "suitable for wet locations." The fixture type, lamp, and ballast information should be verified to match the submittals before fixtures are installed. The electrical engineer, during the final inspection, shall verify proper switching of fixtures.

4-16.07B Lighting Control Panels

Reserved

4-16.07C Lighting Poles

Reserved

4-16.08 Undertruck Lighting System

Reserved

4-16.09 Standby Generator

Reserved

4-16.10 Corrosion Control

Relevant specifications may be included in your project to protect underground piping from corrosive soil conditions or stray direct current conditions, and are found in SSP 99-16643, *Corrosion Control*. Some uses of this are for light rail stations with buried pipes; to reduce corrosion of buried fuel or hydraulic pipes; and buried tanks.

If corrosion control is in the electrical section of your project special provisions, there should also be the companion specification, *Cathodic Protection* in Division 15, *Mechanical Work*, under SSP 99-15950.

Contact the project electrical and mechanical engineers and make sure the project plans and specifications are followed. The designer(s) will inform you of key points to witness during the system installation. Most contracts will require the Contractor to have the cathodic protection tested by a licensed technician. The test should include testing the coating, isolation, and system performance according to ANSI/NACE standards.

Field inspection of the pipe coating prior to backfilling is necessary.

4-16.11 Fire Alarm and Detection System

SSP 99-16722, *Fire Alarm and Detection System*, covers this item–which requires a deferred submittal by the Contractor; see Chapter 3, *Contract Administration*, Section 3-8.02, *State Fire Marshal Deferred Submittals*, for additional guidance. The Contractor submits to DES OTA (which would coordinate reviews by OEMWW) engineers for review of completeness, and then submits to the State Fire Marshal (SFM) in GOVMOTUS (software used by SFM) for review and approval; after SFM approval, OEMWW engineers will approve the submittal for the Department. The submittal must contain SFM original contract permit number, and related code information (building data/code analysis). Note that OEMWW represents the Office of Electrical, Mechanical, Water and Wastewater Engineering units within the DES Office of Structures & Engineering Services (SES).

Like the intrusion alarm system, the conduit system is not shown on the project plans but required, and we check for it during the submittal and installation phases of the work. State Fire Marshal involvement most likely will be required for any fire alarm system installation. They (SFM) should be contacted very early in the project, so any concerns are addressed before they become issues.

4-16.12 Intrusion Alarm System

SSP 99-16724, *Intrusion Alarm System,* includes the specifications for this item. The project plans show the location of the system components and call for installation of conduits for wiring. The project plans do not show any conduit. It is the Contractor's responsibility to design the conduit system. We check the Contractor's design both during the submittal phase and when conduits are being installed. The building security personnel and the electrical engineer conduct inspection and operation of the intrusion alarm system.

If the intrusion alarm is a combination system with the Fire Alarm and Detection system, it is a deferred submittal by the Contractor and follows the same review and authorization as described in the preceding section. Check with the SFM to verify if a combined fire-intrusion alarm system is allowed in the jurisdiction.

4-16.13 Weigh Station Message Sign

Reserved

4-16.14 Well Pump Control Stations

Reserved

4-16.15 Sewage Lift Station

Reserved

4-16.16 Aerator Pump Control Station

Reserved

4-16.17 Rain Sensor Control Panel

Reserved

4-16.18 Grounding and Bonding

4-16.18A Service Equipment

It is critical that the service equipment be properly grounded and bonded. This shall follow what is shown on the project plans. The special provisions require grounding bushings and jumpers at all metal conduits, including service conductors, feeders to separate buildings, and grounding electrode conductors. Figure 4-16.42 shows grounding bushings and conductors connected in an automatic transfer switch

enclosure of an MSB. If there is any confusion about this topic, contact the electrical engineer. See Appendix E-4, *Electrical Grounding,* for additional details on the topic of grounding.

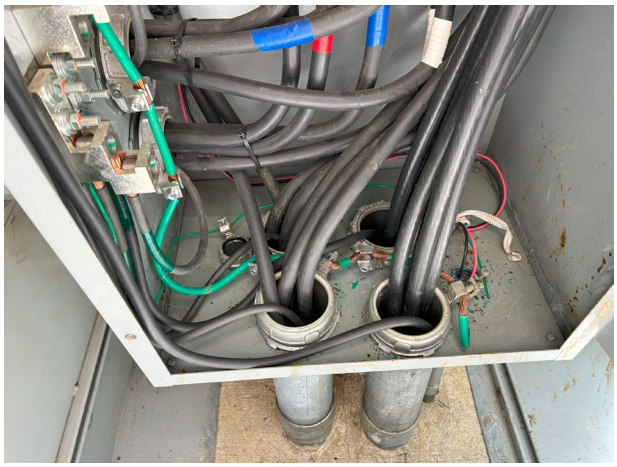


Figure 4-16.42. Grounding Bushings and Conductors Connected in a Transfer Switch Enclosure

4-16.18B Ground Rod Installation

The ground rod installation should be observed by the SR to make sure it follows the plans. For ground rods, a minimum of 8 ft of the rod shall be driven into the soil, and this must be verified. Figure 4-16.43 shows a ground rod being driven into the soil. For Ufer ground rods, a minimum of 20 feet of #2 conductor (or larger) or 1/2-inch uncoated reinforcing steel (or larger) shall be installed in the concrete foundation within 2 inches of the soil; see Figure 4-16.46 for a Ufer wire illustration. Figure 4-16.44 shows a #4 rebar ground rod extending above the slab and connected to grounding conductors and a grounding plate. Figure 4-16.45 illustrates an example of a ground rod and conductor connected in an MSB transfer switch compartment.



Figure 4-16.43. Driving a Ground Rod



Figure 4-16.44. Grounding Conductor Connected to #4 Rebar Ground Extending Above the Slab



Figure 4-16.45. Ground Rod and Conductor Connected in MSB Transfer Switch Compartment



Figure 4-16.46. Bare Ufer Ground Wire Installed in Soil Around a Fuel Tank Pad

4-16.18C Enclosure and Equipment Grounding

All electric service equipment, metal enclosures for all conductors, and connected electric equipment are grounded to the earth. This grounding is accomplished by a system of equipment grounding conductors, metal raceways, bonding jumpers, and/or other authorized devices and fittings necessary to provide electrical continuity between all system components and a grounding electrode.

The word to keep in mind is continuity. An example would be the path from a remote metal light pole via metal conduits with grounding bushings and bonding jumpers at underground pull boxes, grounding conductors through non-metallic conduits, and through a final path to the grounding electrode.

At locations where receptacles are installed into grounded boxes, an equipment grounding jumper is required to connect the receptacle grounding terminal to the box. An exception to this is receptacles in flush boxes that are designed and listed for establishing the ground by means of a contact device or yoke.

4-16.18D Grounding of Piping and Metal Building Frames

The NEC requires that all interior metal piping systems that may become energized shall be bonded to an adequate ground. Figure 4-16.47 shows metal piping being grounded. The grounding details are usually shown as part of the building's electrical plans.

If grounding details are not provided for in the plan details or notes, the SR should contact the electrical engineer for clarification. This contact should also be made when remodel projects utilize existing wiring, and the bonding system is not complete. Structural Design's policy (SES-OTA) also includes the grounding of the framework of metal buildings.

See Appendix E-4, *Electrical Grounding,* for additional grounding information and details.



Figure 4-16.47. Grounding Interior Metal Pipes

4-16.18E Bonding and Grounding at Insulating Connections

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

4-16.18F Bonding and Grounding at Various Locations

Bonding jumpers are required where conduit expansion joints are installed. Grounding bushings and jumpers are also required to provide continuity where the conduits terminate at concentric knockouts.

A photo of a grounding bushing is shown on the second page of Appendix E-1, *Items Commonly Overlooked by Contractors*.

4-16.19 Communications Systems

These will be shown on the communication system plans of the project plans, and the specifications for these are in the electrical section but covered under SSP Section 99-27xxxx, which is part of the 50-section CSI format. The relevant items may include telephone, data, radio, and public address systems. SC staff will have to review their particular contract plans and specifications for the items to be provided by the construction contractor, and what items may be provided by the State. The past practice was that the construction contract provided empty conduit and pull strings for communications systems and the State came in with a separate contractor to install cabling and make connections. In recent and current projects, the cabling, connections, and some equipment and racks are included in the construction contract.

4-16.19A Telephone and Data systems

This work will include conduits, cabling, and outlet jacks for telephone and data systems. The cabling currently used is Category 6A cables or current technology cables, and may include fiber optic cables.

4-16.19B Radio Communication Systems

Follow the project plans and special provisions for the type of cabling, outlet jacks, and equipment to be installed. An important item to remember in radio communications is that this system needs a separate ground and cannot be connected to the electrical power ground, or it will create interference in the radio.