

Specification Section 16001 Electrical Work

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Revision 3

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Appendix A: Electrical Circuit Request and Allocation Procedure

Change Log

Rev. No.	Changed By	Date	Change Description	Pages Changed
0	KLB	10/18/10	FMOc branding and formatting. Edited for grammar, punctuation, and general writing improvements.	All
1	JCG	06/27/11	Changed spec_lev3 style from Lucida Sans 10 bold to Times New Roman 11 to eliminate excessive boldface text. Replaced some section breaks with page breaks.	All
2	EB	11/4/11	Clarified motor disconnecting means requirements. Updated NEMA ratings for outdoor enclosures. Updated removals and demolition section to clarify when to remove Technical Security Systems.	7-9, 11
3	EB/KLB	4/6/12	SME revised Overcurrent Coordination Study description, 2.06.B regarding allowed switches, added section 2.12, Heat Trace, revised 3.03.D regarding raceways and other minor wording, and added a section on Arc Flash Labels as section 3.10, expanding Chapter 3 by one section.	Various

Part 1 - General

1.01 Summary

- A. This section covers the construction and installation of building electrical power systems and related equipment, including dedicated exterior services to building-related outdoor equipment. It does not cover electrical site infrastructure. Provide all labor, materials, services, equipment and appliances to complete the installation of the complete electrical system in accordance with the Specifications and contract documents. The work covered by this section consists of performing all related operations, including cutting, channeling, and chasing, as necessary for the installation of the complete electrical system.

1.02 References

The current editions of the following standards are a part of this specification (international, national, state, and municipal Construction Codes as adopted, unless the contract documents specify a different Code is to be used):

- A. SNL Construction Standard Specifications and Drawings

Number	Title
Section 01065	Environment, Safety, and Health for Construction Contracts
Section 01330	Submittal Procedures
Section 02584	Underground Ducts and Utility Structures
Section 09900	Painting
Section 13100	Lightning Protection
Section 16475	Primary System Safety Requirements
Section 16501	Fluorescent Luminaires
Section 16514	Electrical High-Intensity-Discharge (HID) Luminaires and Lamps
Section 16521	Exterior Lighting Units
Section 16742	Intra-Building Telecommunications System
E-0006STD	Standard Symbol List and General Notes

- B. American National Standards Institute (ANSI)
- C. Illumination Engineering Society of North America (IESNA)
- D. Insulated Cable Engineers Association (ICEA)
- E. National Electrical Installation Standards (NEIS)
- F. National Electrical Manufacturers Association (NEMA)

G. National Fire Protection Association Standards (NFPA)

H. Underwriters Laboratories[®], Inc. (UL)

1.03 Definitions

SCO	SNL Construction Observer
SDR	Sandia Delegated Representative
SNL/NM	Sandia National Laboratories, New Mexico
Accessible	Capable of being directly and safely reached (including standing properly on a ladder) and worked on by a Craftsperson without removing or reaching over other items, such as ceiling grid, light fixtures, or mechanical equipment. (Removal of ceiling tiles and opening access ways is expected.)

1.04 Submittals

- A. Shop drawings must be submitted as directed in Section 01330, *Submittal Procedures*, and for all equipment furnished by the Contractor with internal wiring and controls differing from contract drawings, or not shown on contract drawings.
- **Note:** Control wiring must not be installed before these drawings have been submitted and approved.
- B. The following requirements are in addition to specific submittals for individual systems or equipment:
1. Except where specifically exempt by directions on contract drawings, electrical or electronic devices and assemblies must be furnished with complete wiring diagrams, sequence of operation, and communication interfaces with other devices.
 2. Internal wiring shop drawings must include complete elementary (ladder) diagrams, plus complete wiring diagrams, showing wiring internal to the unit, in its relative location.
 3. Programmable electrical or electronic devices, assemblies, or equipment must be furnished with complete instructions and accessories for programming the unit, along with documentation of the initial furnished program, communication protocol, and sequence of operation.
- C. Shop drawings are required for any substituted equipment furnished by the Contractor that results in changes to control or power wiring as shown on contract drawings. This includes circumstances where substitute components, control schemes, or power wiring are presented and approved that cause a change in the following:
1. Size, number, or type of wires
 2. Size of conduit and its routing
 3. Connection changes
 4. Sequence of operation

- D. If any of the changes described in 1.04C occur, new shop drawings showing the following must be submitted:
 - 1. Elementary ladder diagram
 - 2. Conduit plan
 - 3. Wiring diagram
 - 4. Conduit identification schedule
 - 5. Sequence of operation
- E. Drawings must include each diagram or plan of the contract drawing that is affected.
 - 1. Drawings must be provided of the same size as the original construction drawings, and must be reproducible copies.
 - 2. If the changes are minor and the Contractor chooses to do so, a print of the original contract drawing can be made, and changes noted for approval. This drawing must become part of the as-built documentation submitted near the conclusion of the work.
- F. Overcurrent Coordination Study: Provide for all new or modified electrical equipment to include, but not limited to: fuses, circuit breakers, panel boards, switch gear, and motor control centers (MCCs). After providing submittals of equipment to be purchased, the Contractor shall obtain Overcurrent Coordination Study (via the RFI process) from the Engineer of Record. The information provided should clearly identify manufacturer, product number, frame rating, trip setting, number of poles, voltage rating, and short circuit withstand (a.k.a. Symmetrical Ampere Rating or AIC Rating).

1.05 Quality Assurance

- A. All work performed in accordance with the specifications listed in section 1.02 must be in strict compliance with OSHA regulation 29 CFR 1926, Subpart N. Particular attention is directed to *Safety-Related Work Practices*, 1926.416, and *Lockout and Tagging of Circuits*, 1926.417.

Part 2 - Products

2.01 General

- A. All electrical materials must be new and as listed by UL, or other nationally recognized testing laboratory for the intended application, unless specific exemption is made in the contract documents.
- B. All similar materials and equipment must be the product of the same manufacturer, or listed as an assembly thereof.
- C. Materials and equipment must be the standard product of manufacturers regularly engaged in the production of such material and must be the manufacturer's current and standard design.

2.02 Conduit and Tubing

- A. Rigid Steel Conduit (RSC): Rigid, threaded, thick-walled, zinc-coated on the outside and either zinc-coated or coated with an approved corrosion-resistant coating on the inside.
- B. Rigid Aluminum Conduit: Not permitted unless specified on drawings.
- C. Intermediate Metal Conduit (IMC): Rigid, threaded, lightweight steel, zinc-coated on the outside and either zinc-coated or coated with an approved corrosion-resistant coating on the inside.
- D. Rigid Nonmetallic Conduit: Schedule 40, high-impact polyvinyl chloride (PVC) with 5,000 psi tensile strength at 73.4 degrees F, approved for 90 degrees C, conductors.
- E. Electrical Metallic Tubing (EMT): Milled steel, zinc-coated on the outside, and either zinc-coated or coated with an approved corrosion-resistant coating on the inside. EMT factory-formed with an integral locking nut and bell on one end can be used in lieu of a separate coupling, but only when the conduit sections are in a NEMA 1 environment, or as listed.
- F. Flexible Metal Conduit (FMC): Commercial, galvanized steel; comply with UL 1, *Flexible Metal Conduit*.
- G. Liquid-Tight Flexible Conduit: Flexible galvanized steel tubing with extruded liquid-tight, sunlight-resistant PVC outer jacket, compliant with UL 360, *Liquid-Tight Flexible Steel Conduit*.
- H. Expansion Fittings: Malleable iron, hot-dipped galvanized, with factory-installed packing and a grounding ring.

2.03 Conductors

- A. Unless otherwise noted, all conductors must be annealed copper with minimum 98% conductivity and must conform to the applicable standards of UL, ANSI, and ICEA.
- B. Branch circuit conductors must not be smaller than No. 12 American wire gauge (AWG) copper wire.
- C. All conductors No. 8 and larger must be stranded.

- D. Unless otherwise specified, the minimum size for Class 1 remote-control and signal circuits must be No. 16 AWG, and for Class 2 low-energy control and signal circuits, No. 20 AWG.
- E. The use of solid or stranded wire must meet the equipment manufacturer's installation requirements.
- F. Unless otherwise specified, all conductor insulation must be type THHN or THWN for 600V and below. Other types of conductors must be installed only where shown on drawings.
- G. All conductors must be color-coded according to SNL Standard Drawing E-0006STD.
- H. Metal-clad cable (MC cable) or armored cable (AC cable) can be used for branch circuit wiring of 120/208 volt receptacles, 120/277 volt lighting, and similar terminal loads such as valves, dampers, and variable-air-volume units, where it meets the following requirements:
 - 1. The cable can be concealed in interior (nonstructural) walls and Dowcraft® wall partitions only when run vertically from locations, or above accessible ceilings where its use can be noted.
 - 2. The cable can be used as a terminal branch circuit, but not as a feeder.
 - 3. The cable must not be surface-mounted.
 - 4. The cable conductors must be copper, minimum #12 AWG thermoplastic high-heat-resistant nylon (THHN), with green-insulated copper ground.
 - 5. The cable conductors must be color-coded according to Standard Drawing E-0006STD. When the cable's integral insulation color is not in compliance with this requirement, apply colored sleeves at the accessible points.
 - 6. The cable outer jacket can be aluminum or steel, and can further be coated with a PVC or similar jacket where required for the installation conditions.
 - 7. The maximum number of conductors allowed in a single cable assembly is limited to 5, including the neutral and ground conductors.
 - 8. The cable must not be used for fire alarm devices and associated circuits.
 - 9. The cable can be used as a flexible terminal connection when the drawings otherwise call for one in a NEMA 1 environment. Maximum length must not exceed 3 feet, except for luminaire whips.

2.04 Outlet, Junction, and Pull Boxes

- A. Outlet Boxes
 - 1. Only zinc-coated or cadmium-plated sheet-steel boxes, of a class to satisfy the conditions for each outlet, can be used in concealed work.
 - 2. Boxes mounted on the outside of the building walls must be cast construction, with threaded hubs and gasketed covers.
 - 3. Switch, telephone, and receptacle outlet boxes must not be less than 4 inches square, and fitted with appropriate plaster rings where necessary to set flush within the finished surface.
 - 4. Outlet boxes for exposed work must not be less than 4 inches square with appropriate covers for surface work. "Handy" boxes can be used in accordance with the National Electrical Code® (NEC) requirements. Cut-in boxes can be installed for nonexposed work.
 - 5. Fixture outlet boxes on ceilings must not be smaller than the 4-inch octagonal type.

- a. Fixture outlet boxes in concrete ceilings must be of the 4-inch octagonal type, set flush with the finished surface.
- b. Fixture outlet boxes in plaster or similar ceilings must be fitted with open covers (plaster rings) set to come flush with the finished surface.
6. Each box containing an equipment grounding conductor serving motors, lighting, fixtures, or receptacles must be provided with a grounding terminal.
 - **Note:** The grounding terminal must be green-colored.
7. A device plate that suits the device installed must be supplied for each outlet.
 - a. All outlet cover plates on unfinished walls or on any surface-mounted devices must be zinc-coated sheet metal, having rounded or beveled edges.
 - b. Unless otherwise indicated, all plates on finished walls must be ivory-colored metal or heavy-duty nylon. High-impact (flexible) plates must not be used.
 - c. Screws must be metal with counter-sunk heads that match the finish of the plate.
 - d. The use of sectional device plates is not permitted.
 - e. For exterior outlets and switches, provide a cover that retains its weatherproof rating when the device is in use (cords plugged in and switch on).

B. Junction/Pull Boxes

1. Pull boxes must be constructed of code-gauge galvanized sheet metal, not less than the minimum size recommended by the NEC.
2. Boxes must be furnished with screw-fastened covers unless otherwise specified.

2.05 Wiring Devices

A. Receptacles: All receptacles must be industrial specification grade (commercial specification grade not allowed) of the type shown on Standard Drawing E-0006STD, or as specifically described on the drawings.

1. Building-mounted singlephase and multiphase twist-lock and other special receptacles up to 50 amps per phase must be chosen from approved NEMA configurations as shown on the drawings.
2. Building-mounted multiphase receptacles rated for more than 50 amps per phase must be of the pin-and-sleeve type, with a sleeve length sufficient to conceal the pins during make and break operation, and provided with a 15° back box and hub.

B. Light Switches

1. Light switches must be industrial specification grade (commercial specification grade not allowed), fully-rated for 20 amps at 120/277 volts.
2. Where light switches with pilot lights are indicated in drawings, provide switch as specified in 2.05B.1 with an integral neon or LED light that is illuminated when in the "on" position, unless specifically noted otherwise.
3. Where 3-way or other special switches are required, they must be made by the same manufacturer and of the same quality as the single-pole switches.

2.06 Safety Switches, Disconnects, and Fuses

A. Unless specified otherwise, all safety switches and disconnects must be of the heavy-duty type.

1) Utilize the following chart to provide motor disconnecting means requirements

Motor Type		Disconnecting Means
3 phase		
≥1HP		Heavy Duty Safety Switch
<1HP	>240V _{LL} ¹	Heavy Duty Safety Switch
	≤240V _{LL} ¹	General Duty Safety Switch
1 phase		
≥1HP	use not permitted	
<1HP	120V	SPST toggle switch ²
	208V	DPST toggle switch ²
	240V	DPST toggle switch ²

Note 1: Refers to line to line voltage

Note 2: Provide 20A motor rated extra heavy duty industrial series. Refer to standard drawing E-0006STD for snap switch part number information. Toggle (snap) switches shall be provided with lockout wall plates. In outdoor locations, cast aluminum while-in-use weatherproof covers shall be added.

2) Safety switches and disconnects must be NEMA Type HD and must be horsepower-rated if a motor is served by the device.

B. All exterior-mounted switches and disconnects must be NEMA Type 3, 3S or 4. NEMA 3R/12 is allowed upon approval of Sandia Electrical Engineer. Safety switches and disconnects must be furnished with integral provisions for lockout/tagout (LOTO).

C. Safety switches and disconnects must include the manufacturer's approved equipment-grounding terminal or grounding kit.

D. The Contractor must furnish a complete set of fuses for all switches where fuses are specified. Fuses must be dual-element, time-delay, class "R," rejection type, unless otherwise specified on drawings.

2.07 Cabinets

A. Cabinet boxes must be constructed of zinc-coated sheet steel and must conform to the requirements of UL standard UL 50, *Standard for Safety Enclosures for Electrical Equipment, Nonenvironmental Considerations*. For panelboards, see specification 16440, *Electrical Panelboards*

1. Trims and doors must have a suitable primer coat and a finish coat of a color specifically designated.
2. Each cabinet box must be constructed with interior dimensions not less than those indicated on drawings.
3. Cabinet trim must be fitted with a hinged door and flush latch.
4. Cabinets for exterior mounting must be NEMA Type 3R/12, 3S, or 4.

B. Boxes must be provided with a 3/4-inch exterior grade, single-faced, B-grade or equal plywood backboard mounted inside and painted white, unless otherwise specified on drawings.

- C. Cabinets must have their identification letters shown on engraved plates as shown on Standard Drawing E-0006STD.

2.08 Grounding and Bonding Products

- A. Grounding and bonding products, whether or not indicated on the contract documents, must be of sizes and ratings to comply with the NEC. Where types, sizes, ratings, and quantities indicated are in excess of NEC requirements, the more stringent requirements and the greater size, rating, and quantity indications govern.
- B. Grounding and bonding conductors must be copper. Equipment ground conductors run with circuit conductors, and the grounding electrode conductor must be insulated with green outer finish, unless noted otherwise on the contract documents.
- C. Unless noted otherwise, all grounding conductors No. 8 AWG and larger must be stranded, Class B, in accordance with American Society for Testing and Materials (ASTM) B8.
 - 1. Uninsulated conductors must be bare copper in accordance with ASTM B3, tinned in accordance with ASTM B33, or alloy-coated in accordance with ASTM B189.
 - 2. Use tinned or alloy-coated bare conductors in corrosive environments.
- D. Grounding connectors must be listed and labeled for grounding application. Connectors must be high-conductivity, heavy-duty units.
 - 1. Compression connectors: Must comply with Institute of Electrical and Electronics Engineers (IEEE) STD 837, ANSI/UL-467.
 - 2. Welded connectors: Exothermic-welded type, in kit form, and selected according to manufacturer's written instructions.
- E. Ground rods must be copper-clad steel with high-strength steel core and electrolytic-grade copper outer sheath, molten-welded to core. The minimum rod size must be 3/4-inch by 10 feet long.

2.09 Motors

- A. Exact motor specifications, when required, normally are given in Division 15, Mechanical Specifications; therefore, coordination with Mechanical Contractor is required.
- B. In addition to the requirements in 2.09A, each motor must be sufficient size for the duty to be performed and must not exceed the full rated load when the driven equipment is operating at specified capacity under the most severe conditions likely to be encountered.
- C. Motors to be used with variable-frequency controllers must be rated for such service, and must have shaft grounding provisions and filters to avoid induced-voltage arc damage to bearings and races.
- D. Motors expected to run continuously (or nearly so) must be rated for premium electrical efficiency, unless specifically noted otherwise in Division 15.

2.10 Motor Controllers (Starters)

- A. All controllers must conform to the adopted standards and recommended practices of the Industrial Control Standards of NEMA and Underwriters Laboratories, Inc.

- B. Each motor or group of motors requiring a single control must be provided with a suitable controller and devices that must perform the functions as specified for the respective motors in other sections of these specifications.
1. Each motor, except those with an impedance high enough to prevent overheating because of failure to start, such as clock motors, must be provided with overload protection, either integral with the motor or controller, or mounted in a separate enclosure.
 - a. Unless otherwise specified, protective devices must be of the manual reset type. Manual controllers for motors larger than 1/4 horsepower must be specifically designed for the purpose, and must have a horsepower rating adequate for the motor.
 - b. Where overloads are supplied with controllers, these must be sized after receipt of the equipment to be protected in accordance with nameplate data.
 - c. Overload protection for substituted multispeed motors must be arranged to protect all windings and must be designed so that if an overload occurs in one winding, all windings are disconnected simultaneously.
 - d. Motor controllers must have 120v LED pilot lights as follows:
 - The color for indicating the motor is operating must be red; and for stopped, must be green; unless indicated otherwise on the drawings or in the Motor Control Center Special Construction Specifications.
 - Additional lights for low and high speeds must be included as indicated on the drawings or in the Motor Control Center Special Construction Specifications. Pilot light assemblies shall be supplied with removable lenses allowing lamps to be replaced from controller exterior.
 2. When automatic control devices such as thermostats, floats, or pressure switches are substituted by the Contractor for specified devices, and they control the starting and stopping of motors directly, they must be designed for the purpose and have adequate horsepower ratings.
 - **Note:** When the automatic control device does not have such a rating, a magnetic starter must be used, with the automatic control device actuating the pilot control circuit.

2.11 Lighting Fixtures

- A. Refer to Section 16501, *Fluorescent Luminaires*, for all requirements concerning fluorescent lighting.
- B. Refer to Section 16514, *Electrical High Intensity Discharge (HID) Luminaires*, for all requirements concerning building HID lighting.
- C. Refer to Section 16521, *Exterior Lighting Units*, for requirements concerning exterior area lighting.

2.12 Heat Trace

- A. Provide detailed heat trace “shop drawings” using the A/E firm conceptual design as a go-by. These drawings are to be in SNL CAD-compliant format and submitted as “as-builts” to the A/E for final incorporation to the SNL record drawings.

Part 3 - Execution

3.01 Installation

- A. No employer can permit an employee to work in such proximity to any part of an electric power circuit that the employee could contact the electric power circuit in the course of work, unless the employee is protected against electric shock by deenergizing the circuit and grounding it, or by guarding it effectively by insulation or other means.
- B. Fabrication, erection, and installation according to NEIS standards and the complete electrical system must be done by qualified personnel experienced in such work.
- C. Conduit and equipment must be level, plumb, and true with the structure and other equipment, and in a horizontal or vertical position as intended.
- D. All wiring connections secured by split-bolts, nuts, threaded studs, bolts, screws-into-threaded-buses, and similar devices must use only listed parts designed by the manufacturer to be paired. Choose lugs, studs, and bolts so that nuts can be torqued down on the connection and have a minimum of 3 complete threads, but no more than ½-inch exposed on the open side of the nut. Connectors having a specified torque value for installation must be torqued to that value using a torque-metering tool listed for that use and torque range.
- E. All equipment requiring access for maintenance or future cable installation, (including communications pull boxes) must be installed at an accessible location in an accessible orientation. This placement must be coordinated with all other construction disciplines to ensure accessibility. Hinged-cover pull boxes must be installed such that the hinged lid will open a minimum of 90 degrees, either through an opened ceiling grid or above the ceiling grid. In no case, however, must the distance from the top of ceiling grid to the bottom of an open hinged pullbox cover exceed 12 inches. The New Mexico Electrical Code exemption to NEC Section 110.26(A) does not automatically apply at SNL/NM, unless specifically shown on the drawings.
- F. Immediately prior to acceptance, the Contractor must clean all electrical equipment, both the exterior and interior.

3.02 Removal and Demolition

- A. Unneeded electrical equipment, raceways, and conductors must not be abandoned in place, unless specifically required on the contract drawings for continuity of service and/or possible future use such as security systems in closed areas.
- B. Conductors specifically identified on the drawings to remain must be disconnected, identified, and capped at both ends. Under no circumstances does an unused conductor remain energized.
- C. Circuits serving removed loads must be removed back to the service equipment of the circuits' origin (switchgear, motor control center, or panelboard) as follows, unless specifically shown otherwise on the drawings (circuits associated with security systems in closed areas will be specifically identified as to remain in place or to be removed):
 - 1. Remove all conduit, conductors, switches, controllers, and related electrical equipment from the removed load back to the service equipment point of origin. If a circuit serves multiple loads,

remove the conduit, conductors, switches, controllers, and related electrical equipment dedicated to the removed load back to its interconnection with the circuit to remain.

2. If installed, remove all Facility Control System (FCS) and telecommunications wiring and conduit from the removed load to the source; for example, the FCS field interface device (FID) cabinet or telecommunications drop.
3. Close the penetration of the service equipment and FID cabinets in accordance with NEC section 110.12(A), Mechanical Execution of Work, Unused Openings.
4. Mark the FCS channel, panelboard circuit, or motor control center compartment as "spare." Update the equipment labels and panel schedules appropriately.
5. Patch and paint all penetrations (including restoration of fire rating as necessary) and all anchor points for the removed conduit, conductors, switches, controllers, and related electrical equipment.

3.03 Conduit and Tubing

- A. Conduit systems that are 2 inches or larger, installed outdoors, and terminate on an exterior enclosure that houses an overcurrent device (circuit breakers or fuses) must enter through the side or bottom.
- B. Electrical metallic tubing (EMT) must not be installed in concrete, underground, or through roof penetrations. EMT can be used on the exterior of buildings unless otherwise specified on the drawings.
 1. EMT must use UL-listed watertight compression-type threadless fittings in outdoor applications.
 2. EMT box connectors must be securely fastened to all boxes and cabinets with one locknut.
 3. EMT can be run horizontally concealed in interior (nonstructural) walls only when serving a multioutlet terminal branch circuit.
- C. Rigid galvanized steel (RGS) conduit and intermediate metal conduit (IMC) must be used where shown on drawings, in outdoor locations, for roof penetrations, and where required to meet NEC requirements. For roof penetrations, extend RGS and IMC a minimum of 12 inches above the roof membrane. Rigid and intermediate metal conduit must be securely fastened to all boxes and cabinets with two galvanized locknuts and one bushing installed wrench tight.
- D. When raceways of Rigid, IMC and concrete encased PVC are used for underground applications such as power (**below 600 V**), controls, intrusion alarm, fire alarm and communications (**24 fiber maximum**), they shall be buried at a minimum depth of 24 inches from the top of conduit to grade. When the minimum depth cannot be met due to existing obstructions/site conditions, contact the applicable Sandia Construction Observer (SCO).
- E. Polyvinyl chloride or other types of conduit can be used only where specified on drawings.
 1. When used underground (but not under a building floor slab), provide concrete encasement according to the requirements of Section 02584.
 2. A mandrel ¼-inch to ⅜-inch smaller than the conduit must be pulled through each conduit. A circular wire brush the same diameter of the conduit then must be pulled through the conduit.
 3. Conduit stub-outs must be RGS or IMC, capped, and not encased in concrete for future accessibility. A threaded PVC cap must be installed on both ends, except at manhole walls, to prevent moisture or debris from entering the conduit. For conduits 2 inches or larger, a ¼-inch

polypropylene pull rope must be provided with 2 feet of slack at each end, with the ends secured to a ¼-20 eye-bolt securely attached to the PVC caps. See also the requirements of Section 02584.

4. All empty conduits smaller than 2 inches must have a conduit measuring tape cord (Greenlee #435) provided with 2 feet of slack at each end, unless otherwise shown on plans.
 5. All bends, except for communication and high-voltage duct banks, must be of steel, unless specified otherwise on drawings.
- F. Flexible conduit must be used for terminal connections to all motors, inverters, and resilient-mounted equipment, and to other equipment where specified on drawings, and then only to a maximum length of 3 feet.
1. Metal-clad (MC) cable or armored cable (AC) must not be used in lieu of flexible conduit when there is no other reason to splice the conductors, and then only in NEMA 1 conditions.
 2. Provide liquid-tight flexible conduit in exterior, wet or damp locations, for connections to wet-pipe mechanical systems, or where specified on drawings.
 3. All installations in demountable metal partitions (Dowcraft, VMP) must be run in flexible metallic conduit or MC cable to a junction box located above the panel.
- G. All EMT, IMC, and rigid-conduit couplings must be installed wrench-tight. Threads must be brushed clean to ensure good electrical contact.
- H. Install insulating type bushings, designed to prevent abrasion of wires without impairing the continuity of the conduit grounding system, on rigid-steel conduit, IMC, and rigid-aluminum conduit larger than ½-inch size.
- Insulated bushings must be installed on all raceways for conductors No. 4 and larger at the point of entry into gutters, cabinets, boxes, or motor control centers.
- I. Conduits and tubing must be concealed within the walls, above ceilings, and under slab-on-grade floors where possible, as shown on drawings. Maintain at least 6 inches distance from parallel runs of flues, steam pipes, or hot-water pipes.
- J. Conduits concealed within interior walls must be run vertically to the maximum extent possible, excepting only those instances where the architecture does not permit it (such as an expanse of contiguous windows with receptacles below).
- K. Conduit, cable, and tubing systems not normally requiring future maintenance nor anticipated to require ready access, and that are installed above lay-in ceilings, must be installed as high as possible above the ceiling. Runs must be parallel or perpendicular to walls, structural members, or intersections of vertical planes and ceilings, with right-angle turns consisting of cast-metal fittings or symmetrical, constant-radius bends.
- L. Exposed conduits must be run parallel and perpendicular to the building surface of exposed structural members, and follow the surface contours as often as practical to present a neat appearance. Exposed parallel or banked conduits must be run together to provide a neat appearance.
- M. Bends and offsets must be avoided where possible, but when necessary, must be made with an approved hickey or conduit-bending machine. The use of a pipe tee or vise for bending conduit or tubing is not permitted. Use only UL-listed PVC benders to bend PVC.

- N. Conduit or tubing that has been crushed, wrinkled, or deformed in any way must not be installed.
- O. Each conduit that is buried in or rigidly secured to the building construction on opposite sides of a building expansion joint and each long run of exposed conduit that can be subjected to excessive stresses must be provided with an expansion fitting suitable to the degree of expansion expected.
- P. The Contractor must exercise the necessary precautions to prevent the lodgment of dirt, plaster, or trash in conduit, tubing, fittings, and boxes during the course of installation.
 - 1. Care must be taken to ensure that raceways do not contain any type of debris.
 - 2. A run of conduit or tubing that has become clogged must be entirely freed of these accumulations before use, or must be replaced.
- Q. Holes for conduit installation must not be allowed in steel or reinforced concrete structural members unless approved by the SNL Construction Observer (SCO).
- R. All underfloor or underground conduit runs must be installed such that the last thread is exposed at least ¼-inch above the finished floor, including miscellaneous slabs, interior grade beams, finishes, and other portions of the floor.
- S. Conduit must not be installed within a concrete slab.
- T. All conduit under building floor slabs must be installed a minimum of 12 inches below the bottom of the slab, with a compacted fill between. Service entrance conduit runs must include a tracer wire and warning tape as stated in Section 02584, installed midway between the conduit and the bottom of the slab.
- U. All steel conduits installed in direct contact with the earth must receive a protective corrosion covering in accordance with Section 02584.
- V. See Standard Drawing E-0006STD for conduit color-coding requirements.
- W. Conduit or tubing risers must not be exposed in air shafts or ducts except when approved.
- X. Exposed lengths of conduit, containing medium-voltage power conductors, and operating at more than 600 volts, must be rigid steel conduit. Paint two ½-inch wide red bands spaced 6 inches apart near each coupling, with the operating voltage stenciled in ½-inch letters between the bands.

3.04 Supports and Anchors

- A. Runs of conduit or tubing must have supports spaced not more than 5 feet apart, unless shown otherwise.
 - 1. Conduit and tubing must be supported on approved types of galvanized wall brackets, ceiling trapeze, strap hangers, or pipe straps, secured by means of toggle bolts on hollow masonry units, expansion bolts in concrete or brick, machine screws on metal surface, and wood screws on wood construction. Conduit and tubing must not be hung from, nor attached to hanger support wires used for suspended ceilings, nor suspended from wires using friction clips such as "bat-wings" or similar.
 - 2. Conduit and tubing risers exposed in utility shafts must be supported at each floor level by means of approved U-clamp hangers.

3. Holes for electrical supports drilled in concrete, but not used, must be properly filled with concrete grout.
 4. The cutting of structural members for the installation of supports is not permitted, except by prior written approval from the SCO.
 5. Conduit or conduit supports must not be welded directly to steel structures.
 6. Wooden plugs inserted in masonry or concrete must not be used as a base to secure conduit supports.
 7. Nails must not be used as the means of fastening boxes or conduits.
 8. Wire or perforated strapping must not be used for the support of any conduit or tubing.
 9. Conduits, conduit supports, and associated boxes must not be attached to roof-joist bridging.
- B. All metal angles, channels, straps, and similar pieces used to support electrical apparatus must have all corners ground smooth, and all edges filed or ground smooth before installation.

3.05 Conductors

- A. Power conductors must be continuous from outlet to outlet, and splices must not be made except within outlet or junction boxes. (Junction boxes must be used where required.)
1. Requirements of NEC Articles 374 and 390 for splicing in underfloor raceways must be strictly followed; however, under no circumstances are conductors be "looped" or "fed through."
 2. Conductor color coding according to Standard Drawing E-0006STD is required in all new installations unless otherwise specified on drawings.
- B. Except where approved by the SCO, splices are not allowed in controls wiring, nor in wiring to life-safety devices.
- C. Approved Splices and Terminations
1. For wiring below 600 volts, necessary splices can be made with insulated, screw-type connectors (Wire-Nuts[®] or equivalent) except for conductors sized #8 AWG and larger. For splices in conductors sized #8 AWG or larger, approved in any alarm, communication, or FCS conductors, and those in conductors serving vibrating or rotating machinery, permanent crimp-, bolt-, or solder-type connectors must be used.
 2. All splicing connectors must be furnished with an insulated cover equivalent to the conductor insulation (taping alone is not acceptable). Split-bolt connectors will only be allowed when specific approval from the SCO is obtained before each use.
 3. A connector aid compound must be used at all splices to existing aluminum wire.
 4. Terminal lugs must be used on all stranded conductors.
 5. A Belleville spring washer must be used where existing aluminum terminals are connected to copper or steel terminals with steel bolts.
 6. Medium-voltage splices and terminations must be as-specified, or according to recommendations of wire supplier. Splices must be made only in the presence of the SCO.
- D. Conductor Identification

1. All conductors in panels must be tagged, including neutral and ground conductors. Install a Bradey slip-on label on conductors sized less than # 6 AWG, and install a Panduit #MP-350C tag and tie wrap on conductors sized # 6 AWG or larger. Use a Panduit marking pen PX-O or a Sharpie® permanent marker for labels. These tags must list the circuit number.
 2. All conductors must be additionally tagged in every box and cabinet, including device or fixture (lighting) outlet, and light fixture compartment, with Brady slip-on labels. Wraparound stick-on labels are allowed only where slip-on labels cannot be used. These labels must identify each conductor's panel and circuit number, or terminal number.
 3. Neutral and grounding conductors must be similarly tagged with all the circuits they serve in each box and at the panelboard.
 4. Computer rooms and all other areas where an isolated ground conductor is required must have the ground conductor similarly identified (tagged) with all the circuits they serve in each box.
 5. Box covers must not be installed until approval has been obtained from the SCO for tagging at each box.
- E. Provide UL-listed pulling compound as necessary for conductor pulling.
- F. Equipment used for pulling conductors must be suited and listed for such use by the manufacturer. Before using a steel or conductive fish tape, the Contractor must first visually verify the raceway routing. If there is doubt as to the location of the far end of a conduit, nonconductive fish tape must be used for safety.
- G. When used, MC and similar cable assemblies must be installed according to NEC Article 330. Where MC cable is concealed in walls, it must be run vertically to accessible ceiling space, not horizontally through walls. MC cables must not be used for exposed surface applications, or panel feeders. Use only a manufacturer's approved tool to cut the cable. All such cables must have a green, insulated, copper ground conductor; bare metal and noncopper grounds must not be used.
- H. A shared neutral or super-neutral must not be used with single-phase circuits that are otherwise independent. When part of a multicircuit run in a single conduit, separate neutrals must be identified by a color stripe to identify which phase they serve. A multiphase shared neutral is permitted only where shown specifically on the drawings, and the circuit must be served by a single multiphase circuit protector with one handle or a handle tie, such that a single action disconnects all phases returning on that neutral.
- I. Class I and Class II control and signal cabling installed in conduit must not exceed the conduit fill requirements and pulling tensions of the NEC for power conductors of the same size, or the manufacturer's recommendations, whichever is less.

3.06 Outlet and Junction/Pull Boxes

- A. Boxes must be installed in a rigid and satisfactory manner, either by wood screws on wood, expansion shields on concrete or filled masonry, or machine screws or self-tapping screws on steel work.
- B. Outlet Boxes
1. Outlet boxes must be installed in the locations shown on drawings.

- a. Unless otherwise noted on the plans, the exact locations for outlets must be obtained by scaling drawings.
 - b. Dimensions must be taken from the nearest fixed portion of the building, such as a cross wall or column line, or similar part of the structure.
2. Device Plates
- a. Plates must be installed with four edges in continuous contact with finished wall surfaces, without the use of mats or similar devices.
 - b. Plates must be installed vertically and with an alignment tolerance of 1/16-inch.
 - c. Plates installed in wet locations must be approved for that use.
 - d. All receptacle device plates must be labeled according to Standard Drawing E-0006STD, to include panel and circuit number.
3. Relocations
- a. If outlets are located improperly by more than 6 inches from the locations shown on the plans, they must be removed and reinstalled in proper locations at no additional cost to SNL.
 - b. The Contractor must study the general building plans relative to the spaces surrounding each outlet, so the work fits the work required by these specifications.
 - c. When necessary, the Contractor must relocate outlets so when fixtures or other fittings are installed, they do not interfere with other work or equipment.
 - When these relocations are required, the SCO records this new location on the record plan, and on the Contractor's plan, in red pencil.
 - The Contractor must initial and date both plans.
 - d. Junction/pull boxes for communication systems must be installed according to Section 16742, *Intrabuilding Telecommunication System*.

3.07 Wiring Devices

A. Receptacles

1. All receptacles must be installed as specified on drawings and according to Standard Drawing E-0006STD.
2. Not more than one conductor can be installed under one receptacle termination point.

B. Wall Switches

1. All wall switches must be installed as specified on drawings and according to Standard Drawing E-0006STD.
2. Not more than two switches can be installed in a single gang position of a switch box.
3. Not more than one conductor can be installed under one termination point.

3.08 Safety Switches

- A. Safety switches must not be used as pull boxes or junction boxes, unless otherwise noted on drawings.
- B. All safety switches must have a label affixed according to Standard Drawing E-0006STD. The label must identify the circuit feeding the safety switch, and the equipment served by the safety switch.
- C. Safety switches, fusible and nonfusible, must be installed to comply with the minimum working clearance dimensions of NEC Article 110.26 and Table 110.26 (A)(1).

3.09 Circuit Breaker Settings for Adjustable Trip Devices

The Contractor must obtain the services of the device manufacturer to install or replace the trip plug of an electronic-trip circuit breaker if the existing plug rating does not match the coordination study. The NRTL listing and device warranty must be preserved. The Contractor must request the trip setting from the SDR a minimum of 10 working days prior to adjustment. The adjustment of the trip setting on electronic-trip circuit breakers and adjustable molded-case circuit breakers must be the responsibility of the Contractor.

3.10 Arc Flash Labels

After providing submittals of equipment to be purchased, the Contractor must obtain arc flash calculations (via the RFI process) from the Engineer of Record. Arc flash calculations must include the calorie levels, PPE requirements, hazard categories, and boundary dimensions for all equipment which may be serviced while energized. The contractor must provide the appropriate data to the SNL Electrical Engineer to have Arc flash labels produced. The contractor must provide Arc flash labels on electrical equipment per requirements of drawing E_0006STD before final acceptance.

3.11 Cabinets

- A. Mount cabinets plumb and rigid without distortion of box.
- B. Arrange flush-mounted cabinets so the enclosure front surface is uniformly flush with wall, and exterior door covers wall to enclosure mating surfaces. Provide for future circuits as shown on drawings.
 - 1. If not shown on drawings, stub a minimum of four one-inch (25mm) empty conduits from cabinet into accessible ceiling space or space designated to be ceiling space in future.
 - 2. If not shown on drawings, stub a minimum of four one-inch (25mm) empty conduits into raised floor space, or below slab other than slabs-on-grade.
- C. All surface-mounted cabinets located on finished walls within office and light laboratory areas must be furred from the floor to the ceiling to provide a chase for conduits. The panels used for furring must be removable by sheet metal screws, wood screw attachment, or a similar method.
- D. If the cabinet is a panelboard, switchboard, motor control center, or similar equipment with circuit switching and protection capabilities, install two paper copies of the appropriate SNL template panel schedule in a sleeve inside the door or on the side of the cabinet. The schedule must be an accurate representation of the final circuitry in the cabinet, complete with adjustable settings and equipment descriptions as shown on the template at the time of acceptance testing or commissioning. Download

the current template from SNL's *Engineering & Architectural Standards* web site, and deliver the electronic copy to the SDR when the paper schedules are posted.

3.12 Grounding and Bonding

- A. Grounding and bonding must comply with the NEC, and as shown on drawings. Grounding and bonding must also comply with the following:
1. UL 467, Grounding and Bonding Equipment
 2. Applicable IEEE standards, such as IEEE 142, Recommended Practice for Grounding Industrial and Commercial Power Systems.
- B. A grounding electrode must include ground rods, driven exterior to the facility or as shown on drawings.
1. Top of ground rods must be driven to a minimum depth of 2 feet (0.61 m), unless noted otherwise. Locate ground rods a minimum of two-rod lengths from each other, and at least the same distance from any other grounding electrode.
 2. Interconnect ground rods with bare grounding electrode conductors. Include a test well where shown.
 3. An equipment grounding conductor must be run with circuit conductors from the point of a separately derived service to the loads.
 4. See Standard drawings E-0006STD, ES70001STD, and ES7002STD for additional grounding requirements.
- C. Make connections to minimize the possibility of galvanic action or electrolysis. Select connectors, connection hardware, conductors, and connection methods so metals in direct contact are galvanically compatible.
1. Use electroplated or hot-tin-coated materials to assure high conductivity, and make contact points closer in order of galvanic series.
 2. Make connections with clean, bare metal at the point of contact.
 3. Coat and seal connections involving dissimilar metals with inert material to prevent future penetration of moisture to contact surfaces.
- D. Terminate insulated equipment grounding conductors for feeders and branch circuits with UL-approved grounding lugs. Where metallic raceways terminate at metallic housings without mechanical and electrical connection to the housing, terminate each conduit with a grounding bushing.
1. Connect grounding bushings with a bare grounding conductor to the ground bus in the housing.
- Bond electrically noncontinuous conduits at both entrances and exits with grounding bushings and bare grounding conductors.

3.13 Cutting and Patching

- A. Work must be carefully laid out, in advance, and where cutting, channeling, chasing, or drilling of floors, wall partitions, ceiling, or other surfaces is necessary for the proper installation, support, or

anchorage of the conduit, raceways, or other electrical work, the affected areas must be repaired by skilled mechanics of the trades involved, at no additional contract cost.

3.14 Painting

- A. Electrical items must be painted in accordance with requirements of Section 09900, *Painting*.

3.15 Interruption of Electrical Utilities

- A. Work to be performed during an interruption of electrical utilities must be preceded by all possible preparation, and must be carefully coordinated to minimize the duration of the interruption. Work must proceed continuously until the system is restored to normal.
- B. The Contractor must not interrupt any main interior or exterior electrical utility without written request for an outage and subsequent approval by SNL, nor interrupt any branch circuit to an outlet or item of equipment without verbal approval from the SCO.
1. Written request for outages must be submitted using the Outage Request Worksheet, according to the instructions and advance notice requirements on the worksheet.
 2. Unless otherwise noted on drawings, or directed, any tie-ins or connections to existing utilities or equipment that necessitate interruptions of service must be performed on a Saturday or Sunday, without additional contract costs.
- C. Unless otherwise directed, the manipulation of existing main valves to isolate piping, and the shutdown of fans, pumps, and other equipment will be done by SNL/NM Maintenance personnel.

3.16 Tests and Inspections

- A. After the system installation is complete, and at such time as directed by the SCO, the Contractor must conduct an operating test for demonstration of completion of the work. This test can be in addition to, and part of, a formal system commissioning procedure, but must not replace such commissioning event.
- B. Electrical equipment must not be energized prior to inspection by the SCO.
- C. Ceiling tiles must not be installed prior to inspection by the SCO of any above-ceiling installed electrical equipment.
- D. When requested, the Contractor must test any designated wire, cable devices, and equipment after their installation to assure that all of the material continues to possess all the original characteristics, as required by all governing codes and standards listed in these specifications.
- E. At the time of the operational testing, a complete set of as-built drawings must be given to the SCO.

END OF SECTION

Appendix A: Electrical Circuit Request and Allocation Procedure

Article I Electrical Circuit Request and Allocation Procedure

Purpose

This procedure is used to maintain accurate panel schedules and evaluate work proposed for electrical panelboards, switchgear, and load centers.

Scope

This procedure applies whenever a modification is proposed for an existing electrical panel, such as the installation, removal, or refeeding of a load. All work in electrical panels must be coordinated through the Sandia Designated Representative (SDR). A circuit request must be submitted to, and approved by, the cognizant Systems Engineer (SE) prior to beginning construction. Availability of the circuits, panel capacity, and phase balance must be verified prior to beginning construction.

Responsibilities

Design Engineer/Requester

- Must obtain a circuit assignment from the cognizant SE when submitting a design package for review.
- Must evaluate the proposed design for panel load capacity and phase balance.

Construction Contractor

- Must obtain a circuit assignment from the Design Engineer or SE prior to beginning construction.
- Must verify the circuit being requested is available and usable by visual inspection, and/or the circuit to be removed can be pulled from the panel (circuit breaker may or may not remain) (PPE must be worn as required).
- Must request timely inspection of completed construction and verification of redlines by Construction Observer.
- Must return redlined panel schedule to SDR and SE within 24 hours after construction is complete.
- Must place two (2) copies of the final, updated panel schedule in the panel.

Systems Engineer

- Must review all requests and coordinate which circuits can be used.
- Must identify requested circuits in the Panel Schedule Database by using brackets and revision letters to identify reserved circuit. Expiration date and requester information must be noted for future reference on the panel schedule.
- Must review redlined panel schedule, update the Panel Schedule Database, print two copies of the final panel schedule (with brackets and requestor information removed), and deliver same to the Requestor for placement in the panel.
- Must see that all relevant drawings are updated as required.

Construction Observer

- Verify work is complete and redlines are accurate prior to Requestor sending completed schedule to SE.

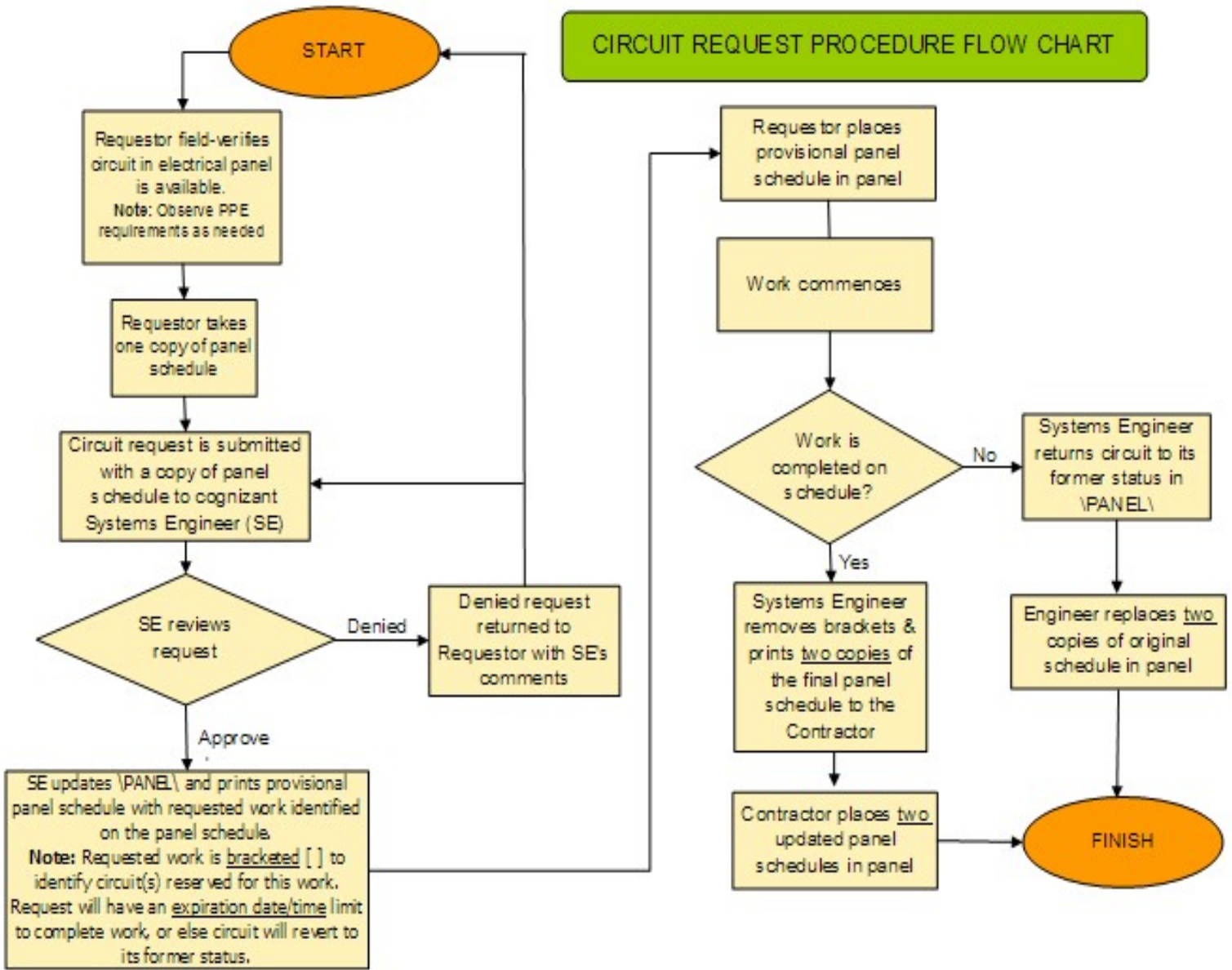


Figure A.1 Circuit Request Procedure Flow Chart