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Section 87 Electrical Systems

4-8701 General

This section includes guidelines for the construction, installation, and inspection of electrical systems.

Review Part 4, "Highway Traffic Signals," of the *California Manual on Uniform Traffic Control Devices*; California Code of Regulations, Title 8, "Electrical Safety Orders," (8 CCR 2299 *et seq.*); and Sections 10-1.02, "Work Sequencing"; 56-2, "Overhead Sign Structures"; 56-3, "Standards, Poles, Pedestals, and Posts"; 75-1.02B, "Galvanizing"; 86, "General"; and 87, "Electrical Systems," of the *Standard Specifications* and their related standard special provisions.

The continuity and insulation resistance tests for each conductor and conductors within cables are performed with the electrical system completely disconnected from the electrical utility.

Usually, continuity is checked by attaching an ohmmeter between the two ends of the conductor. If the conductor ends are too far apart, connect two conductors together at one end and take the measurement for both conductors at the other end. The ohmmeter display should read zero ohms or close to zero. If the ohmmeter reads infinity, there is a break in the conductor. If the ohmmeter has a sound signal, turn on the sound signal and listen for a beep. The beep means there is continuity, no beep means there is a break in the conductor. If there is a break in the conductor, direct the contractor to replace the conductor or cable.

Insulation resistance is measured by attaching a megohmmeter between the conductor wire and the wire insulation. The megohmmeter is set to 500 volts and the test voltage is applied to the conductor for 1 minute. After 1 minute, the resistance value is read and recorded. If the insulation resistance is less than specified, ask the contractor to replace the conductor or cable.

Contact the district maintenance highway electrician, traffic operations engineers, or construction electrical engineers if assistance is needed to review the test results.

Verify the contractor performs a 5-business-day continuous operation test for each completed electrical system.

4-8702 Before Work Begins

Record on the plans any unusual items covered in the specifications but not shown on the plans. Indicate foundation sizes, bolt sizes, and bolt circles on the plan sheet containing the pole schedule.

Review the project with the traffic signal maintenance electricians, the Electrical Design Unit, and the district Traffic Unit, to determine if any changes or revisions are needed.

Electrical systems work often involves many agreements and requires the coordination of activities with outside agencies and utilities. Discuss the status of utility agreements and relocations with the project engineer. Review the resident engineer's pending file and become familiar with the agreements.

Coordinate with utility companies and outside agencies. Notify utility companies and other agencies in advance so they can coordinate their work. Notices may include a request for electrical and telephone services. Coordinate with the district utility coordinator to submit an application and process payment to the utility companies.

Review the project with the contractor to determine where cranes and pile drivers or other equipment will be used. Consult the utility company representatives for any clearance requirements necessary to accomplish the work. Determine any necessary relocations or adjustments as early as possible, to avoid project delays. Contact the district Right of Way Unit if utility facilities must be relocated because of the proposed work or if overhead wires for temporary electrical systems encroach on private property.

4-8703 During the Course of Work

4-8703A General

To document that all items are completed and not overlooked when accepting the work, complete Form CEM-5803A, "Electrical Systems Inspection Checklist," for each electrical system. File a copy of the form in Category 58 of the project file and provide a copy to the district electrical maintenance representative.

Verify that adequate warnings and safeguards, such as signs, lights, barricades, and barriers, are set in place.

Inspect these activities when the work is underway:

- Conduit installations
- Conductor and cable installations
- Foundation excavations
- Concrete placement
- Detector installations
- Field wiring

Before contract acceptance, obtain from the contractor a Geographic Information System (GIS) mapping file for:

- Conduit
- Pull boxes
- Cabinets
- Service equipment enclosures
- Standards

Review the GIS file to make sure the information is complete. Verify GIS coordinates are measured as specified, are in decimal format, and have 6 significant figures after the decimal.

Verify that the contractor locates and field marks existing facilities within 10 feet of any excavation before performing any work that could damage or interfere with the existing facility.

If communication cables or utility lines are encountered during an excavation, contact the utility owner.

Verify that existing systems damaged by the contractor during construction are repaired or replaced within the specified time. If the system cannot be fixed, the contractor must provide a temporary system until the system can be fixed.

Verify that jacking pits, foundation holes, and excavations are covered according to the specifications, especially next to pedestrian facilities.

Check all metal components for proper bonding and grounding.

Before placing new systems into operation and opening to traffic, check that all lights, signs, pavement delineation, and pavement markings are in place and working properly.

Complete all necessary forms and place them in the project files, including but not limited to the following:

- Notification to the appropriate district offices of dates electrical facilities were placed in or removed from service.
- Notification to the district electrical billing coordinator by submittal of the completed utility service request form. This request provides the necessary information for the billing, inventory items, and turn-on and turn-off dates.

Record all changes into the as-built plans. Provide a copy of the as-built plans to the district electrical maintenance office and the district traffic operations office. Submit the original as-built plans to the district construction office.

4-8703A (1) Conduit Installation

Verify that conduit is installed using the methods specified in Section 87-1.03B, "Conduit Installation," of the *Standard Specifications*.

Verify the conduit used is the specified type and the same size between pull points. Do not allow the use of reducing couplings.

To prevent damage to conduit, do not allow placement of materials, or persons to stand, on the conduit during installation.

Check that conduit of the same material is used when extending existing conduit. Conduits of different materials must be terminated in a pull box.

Verify that all exposed threads, field cut threads, and damaged surfaces receive a corrosion protection coat.

Verify that conduit terminating in a pull box extends into the box in a manner that will keep the box as clear as possible for making connections and placing transformers.

Verify conduit ends are capped until the conductors or cables are to be installed.

Check that all conduit terminations, such as at pull boxes or foundations, are provided with bushings before installing the conductors or cables.

Check that conduit to remain empty has a pull tape with at least 2 feet of slack at each end and the pull tape is attached to the ends of the conduit.

Verify that conduit ends are sealed after cables or pull tape are installed.

Check all conduit for proper bonding and proper connections.

Check conduit is not damaged by the contractor, when installing pull box markers, sign posts, and guardrail.

4-8703A (1a) Metal Conduit

Verify conduit ends are square and field cuts are made with a pipe cutter as specified.

Check the ends of factory-reamed conduit for burrs, and verify field cuts are always reamed.

Prohibit the use of unthreaded connectors for conduit, because they do not have sufficient mechanical strength.

Verify conduit is properly connected, all threads are covered by the coupling and the ends of the conduit are butted tightly together. If threads are exposed, either the connection is not tight or the threads are crossed in the coupling. Conduit threads are not tapered.

Observe the joining of conduit during placement; otherwise, test with a wrench to confirm the joints are tight, but not overly tight. Over-tightening will cause bellmouthing of the conduit end inside the coupling that may damage the conductors during installation. If the conduit is not in a straight line when assembled, the joints will not butt together even when tightened with a wrench.

Check that the contractor uses only approved tools to make field bends. Do not allow bends made on the back of a truck, under a railroad track, or around a tree. A hydraulic bender is best to form a bend that is not too sharp. To make a smooth, 90-degree bend without kinks or flat places, three to four settings of the hydraulic shoe are necessary. Do not allow field bends too close to a coupling, the stress created at the coupling may cause the conduit to fracture at the threads. This fracture may not be discernible at the time, but may cause trouble later. Verify that the contractor keeps the number of bends to no more than 360 degrees between pull points.

Verify that installed bushings are insulated.

4-8703A (1b) Plastic Conduit

Verify the contractor thoroughly cleans the ends of plastic conduit and uses the right amount of solvent cement to obtain a good joint.

4-8703A (1c) High Density Polyethylene Conduit

Witness a minimum of 2 test electrofusion conduit splices before allowing high density polyethylene conduit (HDPE) conduit to be installed. Verify the electrofusion is performed by a person certified by the conduit manufacturer.

Check that HDPE conduit bend radius is a minimum 10 times the outside diameter of the conduit.

Verify inner ducts are installed as one continuous unit between vaults.

Check that conduit does not protrude more than 2 inches inside pull boxes and vaults, and enters at an angle less than 20 degrees from either the vertical or horizontal axis.

Verify warning tape is placed in the trench 6 inches below finished grade.

4-8703A (1d) Conduit Installation on Structures

Confirm that Type 1 exposed conduit is painted the same color as the structure.

In bridges, verify that the conduit riser is out of the way of utilities or manholes in the sidewalk.

Check that conduit placed from a luminaire to a pull box above it terminates in the pull box with sufficient clearance from the walls to permit the placing of the specified sealing fitting without interference from the box cover or transformer.

For new structures verify:

- Conduits leading to soffits and luminaires located below the pull box grade are sealed and watertight.
- Expansion joints are placed in conduit passing through expansion joints in concrete structures. Confirm expansion joints are the type specified and are installed correctly.
- Conduit embedded in concrete structures is plugged flush to prevent breaking or bending it when forms are removed or when backfilling equipment operates close to the structure.

For existing structures, verify conduit is installed and supported according to the contract requirements.

4-8703A (1e) Conduit Installation Underground

Check that conduit is installed at the correct depth.

Verify the contractor places a minimum of 2 inches of sand in the trench before installing conduit and places slurry over the conduit as specified, before backfilling and compacting the trench.

Verify Type 1 or Type 2 conduit installed within a hazardous location is sealed with explosion-proof sealing fittings.

4-8703A (1e) 1 Conduit Installation Under Paved Surfaces

Do not allow the trench-in-pavement method for conduit installation under freeway lanes or freeway-to-freeway connector ramps.

4-8703A (1e) 2 Conduit Installation Methods

When conduit is being placed across existing roadways, take the following into account:

- Directional boring uses a locator and electronics in the boring head, which allows the operator to control the direction and depth of the boring head. This method makes it possible to place the conduit in a precise location, within a fraction of an inch of the planned location.
- The air drill and fishtail bit should be used with the minimum amount of water possible. Too much water saturates the grade and can create voids that may cause the road surface to collapse and the pipe to drop excessively. When the air drill and fishtail bit are used in sandy soil, the water and sand tend to bind the conduit. Common soap powder or detergent may overcome this condition. If not, the use of rotary mud and water will seal off the soil and lubricate the conduit. When rotary mud is used, verify the contractor flushes the mud from the pipe and then removes all the mud from the drill pit before backfilling the drill pit. Failure to thoroughly remove the mud results in a spongy backfill.
- When a hydraulic jack and compressed air are used to push conduit through sand under the pavement, the smaller diameter pipe carries a jet of air. To prevent removing too much soil from under the road and leaving large voids, check that the contractor restricts the amount of air used to jet out sandy material.

4-8703A (2) Installation of Pull Boxes

Check that pull boxes are installed in conduit runs and adjacent to poles, standards, enclosures, and cabinets. Verify pull boxes are spaced according to the contract requirements. Do not allow the installation of pull boxes within the boundaries of concrete pads, curb ramps, or driveways.

Verify pull boxes are placed away from any expansion joint. If pull boxes are improperly shown on the contract plans, provide an alternate location.

Confirm pull boxes are set over a layer of crushed rock, are grouted, and have a drain hole. Verify the grout is sloped towards the drain hole.

Check that the contractor grouts around conduits installed through the sides of the pull box.

Verify that in paved areas, the top of the box is even with the surrounding grade. When the final grades are not established, it may be necessary for the contractor to set the pull boxes temporarily low and raise them to final grade as curbs and sidewalks are built.

Confirm that in unpaved areas, the top of the box is 1¼ inches above surrounding grade. On unpaved slopes, check that pull boxes are kept out of depressions so they do not collect water.

Verify pull boxes are covered when no work is in progress.

For traffic pull boxes verify:

- Minor concrete is placed around and under a traffic pull box.
- The steel cover is bolted to the box when no work is in progress.
- The steel cover is bonded to the conduit.

4-8703A (3) Battery Backup System Cabinets

Check that the battery backup system cabinet is installed to the right of the Model 332L cabinet.

Verify the contractor removed the jumper between terminals BBS-1 and BBS-2.

4-8703A (4) Excavating and Backfilling for Electrical Systems

Require the contractor to notify you 72 hours before excavating.

Restrict excavations on a street or highway to 1 lane at a time, unless the closure charts allow additional lanes to be closed.

Verify backfill is properly placed around pull boxes and conduit.

Verify the contractor disposes of surplus excavated material according to the contract requirements. Refer to Section 3-510B, "Contractor-Property Owner Agreement," of this manual.

4-8703A (4a) Trenching

Do not allow excavations to take place until the contractor is ready to install the conduit or direct burial cable.

Verify that trench backfill is compacted to 90 or 95 percent relative compaction, as specified.

Check that the contractor restores the sidewalks, pavement, and landscaping at the excavation location before excavating at another location.

4-8703A (4b) Concrete Pads, Foundations, and Pedestals

For the foundation requirements for standards, poles, metal pedestals, and posts refer to Section 56-3, "Standards and Poles," of the *Standard Specifications*.

The location of lighting standards is directly related to the gore point on exit ramps and to the lane width on entrance ramps. If necessary, revise the locations of the lighting standards accordingly. Review Sheet ES-11, "Electrical Systems (Foundation Installations)," of the *Standard Plans* for foundation details and locations.

For lighting standards with breakaway or slip bases, verify the top of the foundation is no higher than shown on the plans and the conduit end is below the slip plane.

Verify the foundation excavation is the proper size and depth.

When bar reinforcing steel is required, confirm it is securely fastened and the required clearances are maintained.

Check that anchor bolts are the correct size and securely held in place in the required bolt pattern.

Verify that the concrete used meets the contract requirements. Confirm the contractor forms and finishes the exposed part of the foundations as specified. Review the *Standard Plans* for monolithic pour and grout pads requirements.

Check that foundations and concrete pads are constructed on firm ground.

Verify the top of the foundation and concrete pad are placed according to the contract requirements.

Confirm that an ordinary surface finish is applied and a drain hole is provided when required.

Verify that foundations are cured for 7 days before any equipment is installed.

4-8703A (5) Conductors and Cable Installations

Verify conductor and cable insulation is clearly and permanently marked according to the contract requirements.

Do not allow painting the ends of conductors to obtain the specified insulation colors.

When pulling conductors and cables, a wire trailer is desirable. Verify the contractor pulls the conductors and cables from the reels in such a manner that traffic will not run over the conductors and cables, and pedestrians will not walk on them. Both events can damage conductors and cables.

Check the contractor cleans the conduit before pulling the conductors and cables.

Verify the contractor installs bushings or bells on the conduit ends to prevent damage to the conductors or the conduit when pulling the conductors and cables.

Require conductors and cables to be pulled by hand using a pull tape to prevent damage to conductors by over-pulling. Do not allow the use of winches, trucks, or other mechanical aids. If the special provisions permit power pulling of large conductors, tension measuring devices must be used in accordance with the manufacturer's instructions.

Verify the contractor uses an inert lubricant to prevent damage to the conductor and cable insulation caused by the friction created by pulling or slipping of conductors.

Check that the contractor feeds the conductors and cables into the conduit as a unit, in a sequence determined by the length of the runs, to avoid the slipping of one conductor or cable past another in the conduit.

If additional conductors and cables are being installed in an existing conduit, verify that all existing conductors are removed, the conduit is cleaned with a mandrel or cylindrical wire brush, and the old and new conductors are pulled into the conduit as a unit. Prohibit slipping added conductors past existing ones.

Verify that when conductors from different service points occupy the same conduit or standard, the conductors from one service point are enclosed in flexible or rigid metal conduit.

Check that conductors are identified in accordance with Section 87-1.03F, "Conductors and Cable Installations," of the *Standard Specifications*.

Verify conductors are wrapped and cables are secured to the end of the conduit and the conduit ends are sealed.

Confirm that enough conductor and cable slack is provided in every pull box, vault and cabinet.

Verify that 3 spare conductors are provided in all conduits for ramp metering systems and signal and lighting systems.

Check that a separate conductor or cable is installed for each push button and accessible pedestrian signal (APS).

Prohibit the splicing of a pedestrian push-button or APS neutral conductor into a signal or lighting neutral conductor.

Verify a Number 8 (minimum), insulated, grounding copper conductor is installed in conduits and that it is connected to all-metal components.

4-8703A (5a) Detector Lead-In Cables

Verify the ends of lead-in cables are waterproof before installing the cables in the conduit.

Do not allow splices in the lead-in cables, except at the pull box adjacent to the loops.

Confirm the loops are tested and operational before the contractor splices the loops to the lead-in cable.

Verify lead-in cables are identified and tagged with the detector designation at the cabinet and at the pull box adjacent to the loops.

4-8703A (5b) Conductors Signal Cables

Do not allow splicing of cables, except for 28-conductor cables.

Check that each cable is identified at every pull box as specified.

Verify cable conductors are connected as specified.

Do not allow intermixing of neutral conductors from different cables, except at the controller cabinet.

4-8703A (5c) Signal Interconnect Cable

Prohibit splicing of the signal interconnect cable unless allowed by the special provisions.

4-8703A (5d) Inductive Loop Conductors

Prohibit splicing of inductive loop conductors, except at the pull box.

4-8703A (6) Equipment Identification Characters

If the equipment identification characters are not shown on the plans, contact the district's maintenance office and obtain a list of equipment identification characters. Provide the list to the contractor.

Verify the contractor places the equipment identification characters on a clean surface.

Check that the contractor removes the existing characters from existing or relocated equipment, before placing the new characters.

4-8703A (7) Conductor and Cables Splices

Verify conductor splices are soldered, tight, waterproof, and insulated according to the contract requirements.

Require the ends of unused conductors to be taped to form a watertight seal.

4-8703A (8) Connectors and Terminals

Check the contractor uses crimp-style terminal lugs on stranded conductors.

Verify Number 8 and smaller conductors are soldered to the connectors and terminal lugs.

4-8703A (9) Standards, Poles, Pedestals, and Posts

Review Section 56-3, "Standards and Poles," of the *Standard Specifications* for the requirements for standards, poles, pedestals, and posts.

Verify that the location of standards complies with the Americans with Disabilities Act requirements.

Check that standards and pull boxes are set to the top of the dikes in areas behind asphalt concrete dikes to be filled with dirt to the top of the dikes.

Verify signal standards are placed where the signal faces are not obstructed from the view of drivers and pedestrians. Standards with push buttons or APS must be no more than 5 feet from crosswalks and the push button or APS face must be parallel to the crosswalk to be used. Review Section 4E.08, "Pedestrian Detectors," of the *California Manual of Uniform Traffic Control Devices (MUTCD)*.

For standards with a slip-base assembly, verify:

- Flat washers and heavy hex nuts are installed as shown on sheet ES-6F of the *Standard Plans*.

- The slip base is installed and tightened as specified in Section 56-3, “Standards, Poles, Pedestals, and Posts,” of the *Standard Specifications*, when the standard is on the ground.
- The leveling and top nuts on the bottom slip base are tightened, after the standard is erected.
- Verify that bases for standards on structures are placed:
 - So that anchor bolts align with the bridge rail gap when shown.
 - At least 5 feet from expansion joints, to prevent extra stresses at these critical structural locations.

Require the contractor to rake the standard by plumbing the back side of the tapered standard from the road. A slight rake of the standard about 3 degrees from the roadway prevents the impression that the standard is leaning toward the highway.

Verify standards are bonded with a grounding wire and that the grounding wire is visible after installation according to the contract requirements.

4-8703A (10) Piezoelectric Axle Sensors

Verify the contractor wires the sensors to the controller cabinet.

Witness the contractor perform the required tests and verify the measured values and collected data meet the contract requirements.

4-8703A (11) Utility Service

Verify the contractor provides the service installations from the service point to the equipment according to the contract requirements.

Confirm the contractor furnishes all materials and service equipment for service installations on utility-owned poles.

4-8703A (12) Photoelectric Controls

Verify photoelectric controls are installed according to the contract requirements.

4-8703A (13) Fused Splice Connectors

Verify fused splice connectors for luminaires, except for overhead sign luminaires, are installed in the adjacent pull box. If the pull box is tamper-resistant, check that a fused splice connector with 10 A fuse is installed in the pull box and an additional fused splice connector with a 5 A fuse is installed in the handhole.

Verify fused splice connectors are installed on the primary side of transformers.

Confirm the connections are insulated and watertight.

4-8703A (14) Grounding Electrodes

Verify a grounding electrode and grounding conductor are installed at each cabinet, service equipment enclosure, and transformer.

4-8703A (15) Service Equipment Enclosures

Verify that the location of the service equipment enclosure complies with the National Electric Code, Article 110.26, "Spaces About Electrical Equipment, (600 volt, nominal or less)," minimum clearance requirements.

Confirm that circuit breakers are identified with a description engraved on a phenolic nameplate.

Verify the contractor bonds and grounds all metal conduits and uses a Number 6 or larger grounding conductor between the enclosure and the grounding electrode.

4-8703A (16) Cabinets

Check the area between the cabinet and the foundation is sealed.

Verify the contractor installs and solders the terminals on the conductors.

Confirm all conductors are neatly arranged and laced or enclosed in a plastic tubing or raceway.

Verify all the field conductors are connected to the correct terminal blocks in the cabinet.

Check that telephone demarcation cabinets are installed with the back toward the nearest traffic lane.

4-8703A (17) Signal Heads

Check that signal heads are covered or directed away from traffic until the system is ready for operation.

Verify all signal faces are the same brand and material at each location.

Confirm backplates are installed on all signal heads.

Verify signal mounting assemblies are arranged symmetrically and plumb or level. Check that signal mounting assemblies are oriented to allow maximum horizontal clearance to the adjacent roadway.

Confirm that exposed threads on brackets and bracket areas damaged during installation are cleaned and painted.

Verify conductors are connected to the terminals.

4-8703A (18) Pedestrian Signal Heads

Verify all pedestrian signal heads are the same brand and material at each location.

Check that pedestrian signal heads are covered or directed away from traffic until the system is ready for operation.

Verify signal mounting assemblies are arranged symmetrically and plumb or level.

Confirm that exposed threads on brackets and bracket areas damaged during installation are cleaned and painted. Verify conductors are connected to the terminals.

4-8703A (19) Accessible Pedestrian Signals

Verify all accessible pedestrian signals are the same brand at each location.

Verify the accessible pedestrian signals and the R10 series signs are installed on the crosswalk side of the standard.

Verify the arrow on the accessible pedestrian signal is pointing in the same direction as the corresponding crosswalk.

Confirm that accessible pedestrian signals are calibrated after installation.

Verify the accessible pedestrian signals are programmed with an audible message or tone according to the special provisions.

4-8703A (20) Push Button Assemblies

Verify the push button assemblies and the R10 series signs are installed on the crosswalk side of the standard.

4-8703A (21) Detectors

Confirm that detectors are centered in the traffic lanes at the marked locations.

Verify the distance between the side of an inductive loop detector and a lead-in saw cut from an adjacent detector is at least 2 feet.

Check that detector conductors are the required type. Do not allow splices in the detector conductor.

Verify saw cuts are clean and dry before the detectors are installed, and the residue is vacuumed from the roadway and disposed of away from the project.

Check that the ends of Type 2 inductive loop conductors are waterproof before installation.

Verify that inductive loop detectors have the required number of turns.

Confirm that adjacent inductive loop detectors to be connected on the same sensor unit channel are wound in opposite directions.

Verify that inductive loop conductors in the lead-in saw cut, between the loop and adjacent pull box, are twisted a minimum of 2 turns per foot. Do not allow more than 2 twisted pairs of conductors per lead-in saw cut.

Check that the contractor places the loop conductors in the saw cut with a tool that will not damage the wire's insulation and holds the conductors in place at the bottom of the slot during placement of sealant.

Verify preformed inductive loop detectors are constructed and installed in accordance with Section 87-1.03V(3), "Preformed Inductive Loop Detectors," of the *Standard Specifications*.

Verify that the contractor tests each loop for continuity, circuit resistance, and insulation resistance before placing the sealant.

Verify there are 5 feet of inductive loop conductor slack in the pull box.

Confirm that inductive loop conductors are banded together in pairs at the pull box and each pair is identified with the detector designation and loop number. Verify the start of the inductive loop conductor is identified with the letter “S” and the end with the letter “F”.

Contact the district traffic operations office to test the loops using a reference bicycle if Type D loops are specified for the limit line detection.

If the work modifies more than 50 percent of the existing detectors, Type D loops are required for the limit line detection. Process a change order if Type D loops are not specified.

Complete Form CEM-5803B, “Detector Loop Inspection Checklist” to document inspection of all detectors within a system. File a copy of the form in Category 58 of the project file and provide a copy to the district electrical maintenance representative.

4-8703A (22) Sealants

Verify sealants are applied as specified and at the required temperature.

4-8703A 23) Transformers

Check that transformers are never picked up by the leads.

Verify transformers are wired for the correct voltage and the secondary circuit is grounded.

4-8703B Lighting Systems

Verify the contractor installs all the lighting system components as shown on the contract plans.

Confirm that standards are set such that the mast arm is perpendicular to the centerline of the roadway.

Verify luminaires are installed and oriented as shown on the plans.

Check that conduit between soffit lights is secured and supported with concrete blocks to prevent damage to conduit joints.

Verify soffits are set and securely fastened before concrete is poured to prevent floating during the pour.

Confirm that all field-wired connections are tight and according to the contract plans.

Check that the system is bonded according to the contract requirements.

Verify the contractor performs the conductor and operational tests for the system.

4-8703C Sign Illumination Systems

Verify the contractor installs all the sign illumination system components as shown on the contract plans.

Do not allow modifications to the sign structure or mounting channels.

Confirm that all field-wired connections are tight and according to the contract plans. Verify the contractor performs the conductor and operational tests for the system.

4-8703D Signal and Lighting Systems

Verify the contractor installs all the signal and lighting system components as shown on the contract plans.

Confirm that signal and lighting systems are only shut down during normal working hours and that the local traffic enforcement agency is notified before the system is shut down.

Check that standards are set such that the mast arm is perpendicular to the centerline of the roadway.

Verify signal and pedestrian signal heads are installed and oriented as shown on the plans.

Confirm that the number of conductors, their color coding, and size are correct. Each signal head needs 1 conductor per signal face; additionally, 1 neutral conductor is required in a pole. If a signal head with red (R), yellow (Y), and green (G) arrow faces is to be installed, then 3 + 1, or 4, conductors are needed in the pole. An additional R, Y, G facing at a right angle to the other head on the same pole requires three more conductors, a total of 7. If questions arise about conductor color coding, size, or installation method, consult the district traffic operations office or the electrical maintenance office.

Do not allow splicing of signal conductors; a single conductor must be run to the controller cabinet. Individual leads are needed for testing even if they are connected to the same terminal in the controller cabinet. Only the neutral, pedestrian pushbutton, and lighting conductors can be spliced.

It is often best to attach the mast arm and luminaire to the pole and install the conductors inside the pole before erecting the pole, and complete the splicing in the pull box after pole is erected.

Confirm that all field-wired connections are tight and according to the contract plans, including terminal blocks in the controller cabinet, and signal and pedestrian signal heads.

Verify the contractor performs the conductor and operational tests for the system.

Notify the district traffic operations, the public information office, the electrical maintenance office, the local fire department, the police department, and schools, 2 weeks prior to the turn-on of a signal system.

Never allow a completed signal and lighting system to be placed in operation on a Friday or any day preceding a legal holiday. Before the system is turned on, contact the traffic operations engineer to verify the signal timing and turn on the system.

4-8703E Ramp Metering Systems

Verify the contractor installs all the ramp metering system components as shown on the contract plans.

Verify signal heads are installed and oriented as shown on the plans.

Confirm that all field-wired connections are tight and according to the contract plans, including terminal blocks in the controller cabinet and signal heads.

Verify the contractor performs the conductor and operational tests for the system.

4-8703F Traffic Monitoring Station Systems

Verify the contractor installs all the traffic monitoring station system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans.

Verify the contractor performs the conductor and operational tests for the system.

4-8703G Flashing Beacon Systems

Verify the contractor installs all the flashing beacon system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans.

Verify that the contractor performs the conductor and operational tests for the system.

4-8703H Pedestrian Hybrid Beacon Systems

Verify that the contractor installs all the pedestrian hybrid beacon system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans.

Verify that the contractor performs the conductor and operational tests for the system.

Check that the contractor performs the battery backup system test.

Verify that the pedestrian hybrid beacon system sequence complies with the California *MUTCD*, Chapter 4F, Figure 4F-3 “Sequence for a Pedestrian Hybrid Beacon.”

4-8703I Changeable Message Sign Systems

Verify the contractor installs all the changeable message sign system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans, including the terminal blocks in the controller cabinet and sign assembly.

Verify the contractor performs the conductor and operational tests for the system.

4-8703J Radar Speed Feedback Sign Systems

Verify the contractor installs all the radar speed feedback sign system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans.

Verify the contractor performs the conductor and operational tests for the system.

Check the contractor performs the radar speed feedback sign system test.

4-8703K Interconnection Conduit and Cable

Verify the contractor installs all the interconnection conduit and cable system components as shown on the contract plans.

Confirm that all field-wired connections are tight and according to the contract plans, including the terminal blocks in the controller cabinet.

Verify the contractor performs the conductor test for the system.

4-8703L Fiber-Optic Cable Systems

Within 15 days of fiber-optic cable installation obtain:

- The manufacturer's procedures for pulling fiber-optic cable
- Fiber-optic cable test reports from an independent laboratory for each cable delivered to the job
- Proof of calibration for the test equipment

Check that the contractor maintains the minimum cable bend radius during installation of fiber optic cables.

Verify the contractor installs and labels all the fiber optic cable system components as shown on the contract plans.

Confirm that all field-wired connections are tight, secured, and enough slack is provided as specified.

Check for the installation of fiber-optic markers.

Within 4 business days of the contractor performing the fiber-optic tests, obtain:

- Optical time-domain reflectometer test data files for each fiber-optic cable and segment tested
- Form CEM-5819A, "Cable Verification Worksheet," for each fiber-optic cable tested
- Form CEM-5819B, "Segment Verification Worksheet," for each fiber-optic segment tested
- Form CEM-5819C, "Link Loss Budget Worksheet," for each fiber-optic link tested

File a copy of the documentation in Category 58 of the project file and provide copies to the district traffic operations representative.

4-8703M Temporary Electrical Systems

Review Sections 12-3.33, “Temporary Signal Systems,” and 12-3.34, “Temporary Flashing Beacon Systems,” of the *Standard Specifications*.

Verify the contractor provides, installs, and maintains all the temporary electrical system components as shown on the contract plans.

Verify the temporary electrical system operates according to the contract requirements. The contractor is responsible for the operation, maintenance, and removal of the temporary systems.

4-8703N Existing Electrical Systems

Review the contractor’s work activities schedule so you can make arrangements to maintain existing electrical systems.

Check that the contractor’s activities do not damage or affect the operation of existing systems.

Confirm that standards to be salvaged are completely disassembled.

If the project includes a bid item for maintaining existing traffic management system elements during construction, conduct a preconstruction and post-construction operational status check of the existing electrical system’s elements with the contractor and a district traffic operations office representative. Review Sections 4-1002A, “Work Sequencing,” and 4-1003A, “Work Sequencing,” of this manual.

If work on an existing signal and lighting system requires the detectors to be disconnected or the system to be turned off, notify the electrical maintenance superintendent in advance. When necessary, a Caltrans electrician will place the system temporarily on recall. If the signal must be turned off, provide a 24-hour notice to the appropriate law enforcement agency and arrange for traffic control if necessary.

Verify detectors damaged by the contractor’s activities are replaced within 72 hours. Otherwise, have the district maintenance office replace the detectors and process a contract deduction.

Check that modifications and removal of existing systems are done according to the contract requirements.

4-8704 Level of Inspection

Suggested levels of inspection for typical work activities are:

- Benchmark inspection of preconstruction operational status check of the existing systems before starting any work activities.
- Intermittent inspection of conduit material and dimension.
- Intermittent inspection of conductor gauge, insulation, and color.
- Intermittent inspection of cable insulation and number of conductors, and conductor’s gauge, insulation, and color.

- Intermittent inspection of trench's width, depth, backfill material, and compaction.
- Intermittent inspection of pull boxes installation, grouting, and leveling.
- Intermittent inspection of equipment installation and wiring.
- Benchmark inspection of post-construction operational status check of the existing systems before contract acceptance.

4-8705 Quality Control

Coordinate with Materials, Engineering, and Testing Service to verify the contractor has submitted test samples of:

- Accessible pedestrian signals.
- LED countdown pedestrian signal face modules.
- LED signal modules.
- Luminaires.

Witness the contractor test each conductor and conductors in cables for continuity and insulation resistance. Refer to Section 4-8701, "General," of this manual.

Monitor the 5-business-day continuous operation test performed by the contractor for each completed electrical system.

Witness the contractor test each electronic marker within a buried pull box. Confirm four different points are measured at 90 degrees from each other. Verify the measured pull box location is within 0.5 feet of the actual location.

Witness the contractor test each battery backup system. Verify the electrical system runs continuously for 30 minutes with the power turned off.

Witness the contractor test each piezoelectric axle sensor. Verify the measured values are within the specified requirements. Witness the operational test and verify that the required data is collected and recorded.

Witness the contractor perform the optical time-domain reflectometer test and the power meter and light source test. Check that the measured values are within the specified requirements. Verify that the tests are performed by a certified fiber optic technician.

Verify fiber optic cable splices are performed by a certified fiber optic installer.

4-8706 Payment

Verify all the bid items and review the special provisions as to the method of payment and the condition of the item payments.

Review the contractor's schedule of values breakdown for completeness and accuracy. Section 9-1.16, "Progress Payments," of the *Standard Specifications* provides details for a cost breakdown of lump-sum bid items. Require the contractor to correct any unbalanced unit costs before approving the submittal. You can use this breakdown for progress payments and as a cost basis for change orders.

Approve the cost breakdown before making partial payments on lump-sum electrical items.

For progress payment purposes, keep records of partial payments for each period.

On many projects, electrical systems equipment, and electrical hardware items are eligible for payment as material on hand. Monthly, check the contractor's submittals for materials on hand and verify that materials incorporated into the work have been removed from the submittals. Refer to Section 3-906E, "Materials on Hand," of this manual for additional information.

Deduct the cost for source inspection of poles for electrical systems in accordance with Section 6-2.01E, "Material Source Inspection and Testing" of the *Standard Specifications*.

Deduct the cost of any work performed by Caltrans maintenance crews on new or portions of existing system modified under the contract.

Example 4-87.1. Electrical Systems Sample Checklist

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
ELECTRICAL SYSTEM INSPECTION CHECKLIST
 CEM-5803A (NEW 08/2018)

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CONTRACT NUMBER/CO/RTE/PM		PROJECT IDENTIFICATION NUMBER	
CONTRACTOR NAME		PROJECT DESCRIPTION	
SYSTEM INFORMATION			
SYSTEM DESCRIPTION	LOCATION DESCRIPTION	ROUTE	POST MILE

CONDUIT	Yes	No
Conduits installed are the correct type and size (No reducing couplings used)?	<input type="checkbox"/>	<input type="checkbox"/>
Conduits are installed at the correct depth and backfilled with the specified material?	<input type="checkbox"/>	<input type="checkbox"/>
Number of bends in conduit no more than 360 degrees between pull points?	<input type="checkbox"/>	<input type="checkbox"/>
Metal conduit was bonded?	<input type="checkbox"/>	<input type="checkbox"/>
Pull tape installed in empty conduits?	<input type="checkbox"/>	<input type="checkbox"/>
Insulated bushings or end bells installed on conduit and conduit ends were sealed?	<input type="checkbox"/>	<input type="checkbox"/>
High density polyethylene conduit bend radius are more than 10 times the outside diameter of the conduit?	<input type="checkbox"/>	<input type="checkbox"/>
High density polyethylene conduit does not protrude more than 2 inches into pull boxes and vaults and enters at an angle less than 20 degrees from either the vertical or horizontal axis?	<input type="checkbox"/>	<input type="checkbox"/>
Innerducts are installed as a continuous unit between vaults?	<input type="checkbox"/>	<input type="checkbox"/>
Warning tape placed 6 inches below finished grade in trenches for fiber optic conduit?	<input type="checkbox"/>	<input type="checkbox"/>
Exposed conduit on structures painted the same color as the structures?	<input type="checkbox"/>	<input type="checkbox"/>
Expansion joints placed in conduit passing through expansion joints in concrete on structures?	<input type="checkbox"/>	<input type="checkbox"/>
Explosion-proof sealing fittings installed in conduit within hazardous locations?	<input type="checkbox"/>	<input type="checkbox"/>

PULL BOXES	Yes	No
Pull boxes are the correct type and size?	<input type="checkbox"/>	<input type="checkbox"/>
Pull boxes adjacent to standards are placed on the protected side of the standard?	<input type="checkbox"/>	<input type="checkbox"/>
Pull boxes set on a minimum 6 inch clean crushed rock?	<input type="checkbox"/>	<input type="checkbox"/>
Pull boxes are placed at the correct final grade?	<input type="checkbox"/>	<input type="checkbox"/>
Pull boxes are grouted (including around conduits), have drain hole and grout is sloped towards drain hole?	<input type="checkbox"/>	<input type="checkbox"/>
Pull box covers have the correct markings?	<input type="checkbox"/>	<input type="checkbox"/>
Concrete is placed around and under traffic pull boxes?	<input type="checkbox"/>	<input type="checkbox"/>
Pull boxes steel covers are bonded?	<input type="checkbox"/>	<input type="checkbox"/>

BATTERY BACKUP SYSTEM CABINETS	Yes	No
Cabinet is sealed and secured to the foundation?	<input type="checkbox"/>	<input type="checkbox"/>
Access for power conductors provided between cabinets?	<input type="checkbox"/>	<input type="checkbox"/>
Jumper between terminals BBS-1 and BBS-2 removed?	<input type="checkbox"/>	<input type="checkbox"/>

EXCAVATIONS AND BACKFILL	Yes	No
Trenches are compacted to at least 90% relative compaction or as required?	<input type="checkbox"/>	<input type="checkbox"/>
Foundations for lighting standards are located relative to the gore point on exit ramps and to the lane width on entrance ramps?	<input type="checkbox"/>	<input type="checkbox"/>
Foundations for lighting standards are located relative to the edge of traveled way and hinge point of cut or fill?	<input type="checkbox"/>	<input type="checkbox"/>
The top of foundations and concrete pads is placed according to the contract?	<input type="checkbox"/>	<input type="checkbox"/>
Rebar cages and anchor bolt templates are set as required?	<input type="checkbox"/>	<input type="checkbox"/>
Anchor bolts are the correct size, secured in place and in the correct pattern?	<input type="checkbox"/>	<input type="checkbox"/>
The exposed part of foundations are formed and finished?	<input type="checkbox"/>	<input type="checkbox"/>
Foundations were cured for 7 days before installation of equipment?	<input type="checkbox"/>	<input type="checkbox"/>
Sidewalks, pavement and landscape areas affected by construction were restored by the contractor?	<input type="checkbox"/>	<input type="checkbox"/>

CONDUCTORS AND CABLE INSTALLATIONS	Yes	No
Conductors and cables are the correct type, size, and insulation color, and have the required markings?	<input type="checkbox"/>	<input type="checkbox"/>
Conductors and cables are labeled and identified in pull boxes and cabinets?	<input type="checkbox"/>	<input type="checkbox"/>
Conductors are wrapped and cables are secured to the conduit ends?	<input type="checkbox"/>	<input type="checkbox"/>
Conductor and cable slack provided as required?	<input type="checkbox"/>	<input type="checkbox"/>
3 spare conductors provided in all conduits for ramp metering systems and signal and lighting systems?	<input type="checkbox"/>	<input type="checkbox"/>
A separate conductor or cable installed for each push button and accessible pedestrian signal?	<input type="checkbox"/>	<input type="checkbox"/>
A minimum no. 8 AWG, insulated, grounding copper conductor installed in all conduits and connected to all metal components?	<input type="checkbox"/>	<input type="checkbox"/>
Detector lead in cables waterproof and tagged with detector designations at both ends?	<input type="checkbox"/>	<input type="checkbox"/>

EQUIPMENT IDENTIFICATION CHARACTERS		Yes	No
Equipment identification characters placed on a clean surface?		<input type="checkbox"/>	<input type="checkbox"/>
CONDUCTORS AND CABLES SPLICES		Yes	No
Conductor splices are tight, soldered (no open flame), insulated, and waterproof?		<input type="checkbox"/>	<input type="checkbox"/>
The ends of unused conductors are taped to form a watertight seal?		<input type="checkbox"/>	<input type="checkbox"/>
CONNECTORS AND TERMINALS		Yes	No
Crimp-style terminal lugs installed on stranded conductors?		<input type="checkbox"/>	<input type="checkbox"/>
Connectors and terminals, on . 8 AWG and smaller conductors, are crimped and solder?		<input type="checkbox"/>	<input type="checkbox"/>
STANDARDS, POLES, PEDESTALS AND POSTS		Yes	No
Standards are located in compliance with the Americans with Disabilities Act requirements?		<input type="checkbox"/>	<input type="checkbox"/>
Standards with push buttons or accessible pedestrian signals are located no more than 5 feet from crosswalks?		<input type="checkbox"/>	<input type="checkbox"/>
Standards with slip-base assemblies are torqued as required?		<input type="checkbox"/>	<input type="checkbox"/>
Standards are raked by plumbing the back side of tapered standards?		<input type="checkbox"/>	<input type="checkbox"/>
Standards are bonded with a grounding wire. For standards without a handhole, the wire is visible after installation?		<input type="checkbox"/>	<input type="checkbox"/>
Equipment mounted on mast arms and shafts is secured?		<input type="checkbox"/>	<input type="checkbox"/>
Signal faces are not obstructed from the view of drivers and pedestrians?		<input type="checkbox"/>	<input type="checkbox"/>
PIEZOELECTRIC AXLE SENSORS		Yes	No
Witnessed conductor and piezoelectric axle sensor tests and verified measured values?		<input type="checkbox"/>	<input type="checkbox"/>
Witnessed operational test and verified the required data was collected and recorded?		<input type="checkbox"/>	<input type="checkbox"/>
UTILITY SERVICES		Yes	No
Conduit, conductors and pull boxes installed for electrical and communication services.		<input type="checkbox"/>	<input type="checkbox"/>
PHOTO ELECTRIC CONTROLS		Yes	No
Photo electric control unit mounted facing north?		<input type="checkbox"/>	<input type="checkbox"/>
Enclosures mounted 6 feet above finished grade?		<input type="checkbox"/>	<input type="checkbox"/>
FUSED SPLICE CONNECTORS		Yes	No
Fused splice connectors for luminaires are installed in the adjacent pull box?		<input type="checkbox"/>	<input type="checkbox"/>
For tamper resistant pull boxes, an additional fuse splice connector is installed in the handhole?		<input type="checkbox"/>	<input type="checkbox"/>
Fused splice connectors are installed on the primary side of transformers?		<input type="checkbox"/>	<input type="checkbox"/>
Connector terminals are crimped, insulated, and watertight?		<input type="checkbox"/>	<input type="checkbox"/>
GROUNDING ELECTRODES		Yes	No
Grounding electrodes installed at each cabinet, service equipment enclosure and transformer?		<input type="checkbox"/>	<input type="checkbox"/>
Grounding electrode connected to the ground bus with a no. 6 AWG conductor?		<input type="checkbox"/>	<input type="checkbox"/>
SERVICE EQUIPMENT ENCLOSURES		Yes	No
Enclosure is sealed and secured to the foundation?		<input type="checkbox"/>	<input type="checkbox"/>
Space clearance around the front and back of enclosure complies with NEC requirements?		<input type="checkbox"/>	<input type="checkbox"/>
Service equipment enclosure and metal conduit bonded and grounded?		<input type="checkbox"/>	<input type="checkbox"/>
Circuit breakers labeled with a description?		<input type="checkbox"/>	<input type="checkbox"/>
CABINETS		Yes	No
Cabinet is sealed and secured to the foundation?		<input type="checkbox"/>	<input type="checkbox"/>
Cabinet and metal conduit bonded and grounded?		<input type="checkbox"/>	<input type="checkbox"/>
Conductors are terminated with crimped and solder connectors and are connected to the terminal blocks?		<input type="checkbox"/>	<input type="checkbox"/>
SIGNAL HEADS		Yes	No
Same material and brand of pedestrian signals used at each location?		<input type="checkbox"/>	<input type="checkbox"/>
Signal mounting assembly members installed symmetrically and plumb or leveled?		<input type="checkbox"/>	<input type="checkbox"/>
Bracket areas damaged during installation and exposed threads were cleaned and painted?		<input type="checkbox"/>	<input type="checkbox"/>
Signal heads have backplates installed?		<input type="checkbox"/>	<input type="checkbox"/>
5-section signal heads have the upper bracket tubing secured to the standard?		<input type="checkbox"/>	<input type="checkbox"/>
Programmable visibility faces have been programmed to be visible only from the lanes to be controlled?		<input type="checkbox"/>	<input type="checkbox"/>

PEDESTRIAN SIGNAL HEADS	Yes	No
Same material and brand of pedestrian signals used at each location?	<input type="checkbox"/>	<input type="checkbox"/>
Signal mounting assembly members installed symmetrically and plumb or leveled?	<input type="checkbox"/>	<input type="checkbox"/>
Bracket areas damaged during installation and exposed threads were cleaned and painted?	<input type="checkbox"/>	<input type="checkbox"/>

ACCESSIBLE PEDESTRIAN SIGNALS	Yes	No
Same brand of accessible pedestrian signals used at each location?	<input type="checkbox"/>	<input type="checkbox"/>
Accessible pedestrian signals installed in compliance with ADA requirements?	<input type="checkbox"/>	<input type="checkbox"/>
Accessible pedestrian signals and R10 series signs installed on crosswalk side of standard?	<input type="checkbox"/>	<input type="checkbox"/>
Arrow on accessible pedestrian signals pointed in the direction of corresponding crosswalk?	<input type="checkbox"/>	<input type="checkbox"/>
Audible message or tone programmed by the manufacturer's representative?	<input type="checkbox"/>	<input type="checkbox"/>

PUSH BUTTON ASSEMBLIES	Yes	No
Push button assemblies and R10 series signs installed on crosswalk side of standard?	<input type="checkbox"/>	<input type="checkbox"/>
Push button assemblies installed in compliance with ADA requirements?	<input type="checkbox"/>	<input type="checkbox"/>

SEALANTS	Yes	No
Applied at the specified air temperature using the specified applicator?	<input type="checkbox"/>	<input type="checkbox"/>

TRANSFORMERS	Yes	No
Type and Rated (Volts, Amps, Efficiency) as specified?	<input type="checkbox"/>	<input type="checkbox"/>
Wired for correct voltage and secondary circuit grounded per NEC?	<input type="checkbox"/>	<input type="checkbox"/>

INSPECTED BY		
ENGINEER (Print Name)	SIGNATURE	DATE

