

Section 86 Signals, Lighting and Electrical Systems

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4-8601 General

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Electrical work involving traffic signals, street lighting, illuminated signs, changeable message signs, electrical devices, and communication systems requires a specialized knowledge. The district should retain staff or train sufficient personnel to inspect this type of work.

Highway transportation signal and illumination systems are in a state of evolution, and changes in materials and specifications on successive projects are continually arising. Both the contractor and the resident engineer should be continually alert to this situation because even experienced electrical contractors may not be familiar with all of the work included in current specifications.

In most districts, construction has transportation electrical engineers to act as resident engineers on projects where electrical work is predominant. On projects where electrical work is not predominant, then personnel with electrical expertise can be made available for assistance to inspect electrical work.

In the smaller districts, transportation electrical engineers in the district traffic unit and highway electricians in the electrical maintenance unit are available for consultation. In recent years, the department has been using many more electrical systems in addition to just the traditional traffic signals and street lighting used in the past. These new systems include the following:

- Closed circuit television
- Changeable message signs
- Roadway weather information systems
- Microwave vehicle detection systems
- Other types of current technology devices

For the most part, the major changes consist in the equipment being used. The basic construction features are the same. For design intent and operational requirements, the resident engineer should pay particular attention to the special provisions and have close contact with the project designer and the operational end user.

4-8602 Before Work Begins

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Before work begins, do the following:

- Study the project plans, special provisions, and standard plan details thoroughly. Record on the plans any unusual items covered in the specifications but not shown on the plans. Additionally, in the margin of the plan sheet containing the pole schedule, it can be useful to indicate foundation sizes, bolt sizes, and bolt circles.

- Signal and lighting construction often involves many agreements and requires the coordination of activities with outside agencies and utilities. Contact the project engineer to obtain the resident engineer's pending file and to discuss the status of utility agreements and relocations. At the start of the project, review the resident engineer's pending file to become familiar with such agreements.
- To determine whether changes or revisions are needed, you may also need to review the project with the traffic signal maintenance electricians, the electrical design unit, and the district traffic unit.
- Although the district utilities coordinator coordinates with utility companies during project development, the resident engineer will be responsible for coordinating with outside agencies once the project has entered the construction phase. Provide advance notice and information to the utilities and others so they can plan their work in an orderly manner. When necessary, notices should include a request for electrical energy and telephone interconnection lines. Either the resident engineer or the district utility coordinator should submit an application to the utility company.
- Advise utility company representatives of clearances necessary to accomplish the work. Insufficient overhead clearance requiring utility relocation is the most common obstruction overlooked on contracts that cover improvements to existing highways. To avoid delays, determine any necessary relocations or adjustments as early as possible. Review the project with the contractor to determine the locations where cranes, pile-driving equipment, or other equipment will be used. If utility facilities must be relocated because of the proposed work, refer this situation to the district right-of-way unit. Also, if overhead wires for temporary lighting or signals encroach on private property, refer this situation to the district right of way unit.
- Determine the contractor's schedule of operations so arrangements can be made to maintain existing signals and street lighting.
- Section 86-1.03, "Cost Break-Down," of the *Standard Specifications* provides for a cost breakdown of each lump sum unit of electrical work. Check the contractor's breakdown for completeness and accuracy. Before approving the submittal, call to the contractor's attention any unbalanced unit costs and require their correction. This breakdown can be used for progress payments and also as a cost basis for contract change orders. Before making partial payments on lump sum electrical items, approve the cost breakdown.
- Obtain a list of equipment and materials that the contractor proposes to install, as required by Section 86-1.04, "Equipment List and Drawings," of the *Standard Specifications*. To prevent omissions or irregularities, the resident engineer must check the required list of materials, and the electrical design unit must then recheck the list. For compliance with the contract, ensure the materials are identified with the manufacturers' names, catalog numbers, and other appropriate listings.
- Before any excavation near a known underground utility, ensure the contractor has called the regional notification center. (Reference the "Obstruction" section in your special provisions.) Caltrans is not affiliated with any utility notification centers. Therefore, our facilities cannot be located in this manner. Contact the local electrical maintenance region manager for help in locating Caltrans facilities. For facilities within Caltrans right-of-way, such as irrigation systems, signal and lighting systems, and traffic monitoring stations, you may obtain and verify the latest utility "as-built" from the electrical maintenance unit .

- Promptly order state-furnished materials listed in the special provisions, such as signs, lamps, light emitting diodes (LEDs), signal controllers, cabinets, and other equipment. Also, to control the pickup and delivery of these materials to the contractor, contact all the necessary parties.

4-8602A Materials

For materials, do the following:

- Verify the receipt and proper distribution of Form CEM-3101, “Notice of Materials to Be Used,” which lists electrical materials.
- To determine which materials are assigned for release at the job site, review Form TL-0028, “Notice of Material to Be Inspected.” Also, ensure the contractor delivers with these materials the necessary certificates of compliance (including compliance with Buy America requirements) and test results to the site. You must release or reject the materials in accordance with Chapter 6, “Sampling and Testing,” of the *Construction Manual* (manual).
- As stated in Section 6-1.05, “Trade Names and Alternatives,” of the *Standard Specifications*, the contractor may request permission in writing to make a substitution for a product specified if the substitution is of equal quality and suitability.
- The Office of Materials Engineering and Testing Services, the Office of Structure Design, and the electrical design unit have personnel with technical knowledge to evaluate the suitability of properties, including the electrical characteristics of the items involved. Consult these personnel and give adequate weight to their recommendations as to the acceptability of a proposed substitute.
- The resident engineer must recommend approval or denial of a substitute. Under no circumstances must the supplier or contractor bypass the resident engineer by negotiating with other functions for proposed substitutes on projects under contract.
- Any substitution for a specified product is a change in specifications and must be made by a contract change order.
- For any electrical materials that the plans indicate will be salvaged, checked the condition of the materials before the contractor arrives on the job site. To document the materials’ condition, take photographs. For more information on salvage materials, see Section 3-403B (4), “Surplus and Salvaged Material,” of this manual.

4-8603 During the Course of Work

During the work, do the following:

- During construction, ensure the use of adequate warnings and safeguards in the form of signs, lights, and barricades. Jacking pits or foundation holes where pedestrians may walk must be covered with adequately braced plywood or an equivalent.
- Inspect underground work while it is actually underway because when once such work is complete, an inspection cannot be done. Include in your inspection the placing of conduit and the excavation for and the placing of concrete for signal standards, electrolier bases, and similar items.

4-8603 During the Course of Work

- If communication cables or utility pipe lines are encountered, contact a representative of the utility owner.
- Continuously record all changes into the as-built plans.

4-8603A Foundations

For foundations, do the following:

- The location of electroliers near offramps is related directly to the gore on offramps and to the lane width of on ramps. Keep this fact in mind if it is necessary to revise the locations of the electroliers. For the location of freeway luminaires, see Figure 9-25, “Freeway Lighting,” of the *Traffic Manual*. Also, pay particular attention to the foundation locations shown on Sheet ES-11, “Signal, Lighting and Electrical Systems-Foundation Installations,” of the *Standard Plans*.
- Concrete for electrolier and signal foundations is often placed without forms against the excavation. The resulting rough block of concrete is functionally satisfactory. However, ensure the contractor forms and finishes the exposed part of the footing as specified. To ensure the proper operation of breakaway or slip bases, the top of the foundation must not be higher than the height shown on the plans. Also, the conduit must be below the slip plane. For various standards and foundations as they relate to monolithic foundation pours and grout pads, pay particular attention to the details in the *Standard Plans*.
- During concrete placement operations, ensure that anchor bolts are securely held in the proper position and that the proper size anchor bolts and the correct bolt circle are used. Determine that bar reinforcing steel, when required, is securely fastened and has the required clearances. Verify that the foundation excavation is the proper size and depth, and ensure the specified concrete is used.

4-8603B Standards

For standards, do the following:

- Where areas behind asphalt concrete dikes are filled with dirt to the level of the top of the dikes, ensure the contractor also sets standards and pull boxes to the top of the dikes.
- Before accepting a project, ensure that the grounding of standards complies with specified methods.
- When laying out standards, ensure no obstructions exist that will prevent vehicular or pedestrian traffic from seeing vehicular or pedestrian signal faces. Standards with push buttons must be no more than 1.5 m from crosswalks, and the push buttons must be on the side of the standard nearest the crosswalk.
- Upon setting the standards, ensure that washers are used on both sides of the slip base plate and between the bottom and top slip base plates and that, before erecting the standard, all leveling and top nuts are properly torqued. When using slip base inserts, assemble the top and bottom plates and torque the bolts before placing the standard on the top plate of the slip base assembly.
- For the location of standards with slip bases or slip base inserts, refer to Section 9-11.4, “Slip Bases,” of the *Traffic Manual*. If the exception areas as listed in Section 9-11.4 apply to a planned slip base standard, contact the designer about a contract change order.

- Ensure electroliers on structures are located with regard to bridge rail plans so that anchor bolts may be placed where the bridge rail gap will be. Ideally, keep electrolier bases at least five feet from expansion joints. This practice prevents extra stresses from the electrolier at these critical structural locations.
- A slight rake of the standard, about three degrees from the roadway, prevents the impression that the standard is leaning toward the highway. The standard can be raked by plumbing the side of the tapered standard from the road.

4-8603C Conduit

In general, do the following for conduit:

- For permitted or required methods for placing conduit, check the special provisions. Ensure that the trench backfill is compacted 90 to 95 percent relative compaction depending upon the location. Also, ensure that the backfill is properly placed around pull boxes and conduit.
- Any conduit projecting from solid concrete is likely to be broken or bent when forms are removed or backfilling equipment operates close to the structure. Therefore, even if the conduit will be used in the near future, ensure that when it is embedded in concrete structures, it is plugged flush as shown on the plans. To assist in finding the location of the conduit in the future, mark the concrete and indicate the conduit's location on the as-built plans.
- Ensure that expansion joints are placed in the conduit where it passes through expansion joints in concrete structures. To ensure the joints operate correctly, check the proper type and placement of them.
- Ensure 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 ballasts. Check all conduit for proper bonding and proper connections.
- When conduit is being placed across existing roadways, ensure one of several common methods is used. These methods include directional boring, air drill, fishtail bit, water, hydraulic jack, compressed air, two diameters of conduit(one within the other), and trenching across the pavement. For some of these methods, take the following conditions into account:
 1. Directional boring uses a locator and electronics that are in the boring head. The operator can control the direction and depth of the boring head. Using this method of boring allows the conduits to be placed in precise locations. It is possible to bore across a roadway and come out within millimeters of the planned location.
 2. The air drill and fishtail bit should be used with the minimum amount of water possible. Too much water tends to saturate the grade and wash out large voids that can cause the road surface to collapse and the pipe to drop excessively.
 3. If the air drill and fishtail bit are used in sandy soil, the water and sand will 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 sand and lubricate the conduit. However, if rotary mud is used, ensure that before the backfilling of the drill pit, the contractor flushes the mud from the pipe and then removes all the mud from the drill pit. Failure to thoroughly remove mud results in a spongy backfill.

4. When a hydraulic jack and compressed air are used to push conduit under pavement through sand, the smaller diameter pipe carries a jet of air. To prevent removing too much sand from under the road and so leaving large voids, ensure the contractor restricts the amount of air used to jet out sandy material.
- In bridges, ensure the conduit riser is out of the way of utilities or manholes in the sidewalk.
 - Ensure that conduit placed from a light fixture 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.

4-8603C (1) Metal Conduit

When a 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, generally either the connection is not tight or the threads are crossed in the coupling. Conduit threads are not tapered. Either observe the joining of conduit during placement or test with a wrench to ensure the joints are tight, but not over tight. Over tightening will cause bellling of the end of the conduit inside the coupling and can cause damage to the conductors during installation. If the conduit is not in a straight line when being assembled, frequently the joints do not butt together even when tightened with a wrench. Ensure that conduit ends are square and field cuts are made with a pipe cutter as specified.

Ensure that field bends are not made too close to a coupling. Stress at a coupling frequently causes the conduit to fracture at the threads. This fracture may be covered by the coupling and not be discernible at the time, but the fracture may give trouble at a later date.

Ensure the contractor uses only approved tools to make field bends. The bends should never be made on the back of a truck, under a railroad track, or around a tree. A hydraulic bender is best, while ensuring that the bend 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.

Check the ends of factory reamed conduit for burrs, and ensure field cuts are always reamed. Prohibit threadless connectors for conduit because they do not have sufficient mechanical strength.

4-8603C (2) Plastic Conduit

During installation, plastic conduit, like polyvinyl chloride water pipes and fittings, requires special handling. After installation, ensure the contractor takes special precautions to prevent damage to the conduit when installing pull box markers, sign posts, and guardrail.

To pull conductor wire through plastic conduit, ensure the contractor uses a soft nylon pull rope.

To obtain good, nonthreaded joints for plastic conduit, ensure the contractor takes special care to clean the ends of the pipe and use the right amount of the proper solvent cement.

4-8603D Pull Boxes

For pull boxes, do the following:

- As required under the contract, ensure that pull boxes are installed in conduit runs and adjacent to operating units; however, prohibit pull boxes from being installed within the boundaries of a wheel chair ramp.
- Ensure pull boxes are placed away from any expansion joint. If pull boxes are improperly shown on the plan, provide an alternate location.
- Ensure that in surfaced areas, behind portland cement concrete curbs or in sidewalks, the top of the box is even with the surrounding surface—never depressed. On unpaved slopes, ensure the pull boxes are kept out of depressions so as not to collect water. Pull boxes must be set over a layer of gravel that will provide a means of draining water away from the electrical components within.
- In unpaved, relatively flat areas, ensure the contractor places pull boxes about 30 mm higher than the average surrounding elevation.
- When final grades of surrounding features under construction are not accurately established, it is sometimes necessary to set the pull boxes temporarily low and raise them to final grade as curbs and sidewalks are built.
- Before a bridge deck is poured, if the formed type of pull box is to be used, ensure the contractor first places properly dimensioned wooden pull box templates at pull box locations.
- To provide a drain hole within structures, ensure the contractor places a 19 mm pipe or plastic hose through a hole in the form at the lowest point of the pull box location.
- To determine that the covers are properly inscribed, perform a final check of the pull boxes.
- In illumination and signal work, the voltages employed range from a low of milli-volts for pedestrian push button and detector loops to a high of 5,000 volts for highway lighting circuits. Ensure these voltages are isolated from one another.
- Prohibit the splicing of a pedestrian push button common into a signal or street light common, and never permit a signal conductor to enter a pull box containing a high voltage street lighting circuit. The possibility of a crossover, although remote, is nevertheless present.
- If signal modification work requires the detectors to be disconnected or the signal turned off, give the signal maintenance superintendent prior notice. When necessary, a Caltrans electrician will place the signal temporarily on recall. If the signal must be shut down completely for a time, give the appropriate law enforcement agency 24 hours notice to provide police protection and traffic control.

4-8603E Conductors

For conductors, do the following:

- One conductor is needed for each separate signal section, plus one neutral and three spares in a pole. If one R, Y, G head is to be installed on the pole, then 3+1+3 or 7 conductors are needed. An additional R, Y, G facing at right angle to the other head on the same pole requires three more conductors, or a total of ten.

Arrow lenses generally need an additional conductor each. If questions arise concerning conductor color coding, size, or installation method, consult with the district traffic unit or the electrical maintenance unit.

- Despite the fact that more than one field conductor may go on the same terminal at the controller cabinet, do not allow these conductors to be spliced at a pull box and a single conductor to be run to the controller cabinet. Individual leads are needed so that testing can be done at the controller cabinet. (Only the neutrals, pedestrian push button, and lighting conductors can be spliced.)
- On 9.1 m poles, the best job can often be obtained by installing the luminaire conductors inside the pole before erection and then splicing to leads in the pull box after erection. Luminaires and mast arm signals can also be attached to the poles before raising. To reach from the pull box to the terminal block on the standard without additional splices, ensure the contractor leaves sufficient slack conductor in the pull box. Splices are only permitted at the locations stated in the specifications. Checking for tight connections and splices in all wiring is extremely important.
- When pulling conductors, a wire trailer is desirable. Ensure the contractor pulls conductors from the reels in such a manner that traffic will not run over the conductors and that pedestrians will not walk on them. Both events can cause damage to the conductors. To prevent damage to small conductors by overpulling, the *Standard Specifications* require that the conductor be pulled by hand. Do not permit the use of winches, trucks, or other mechanical aids. The special provisions may permit power pulling of large conductors. If so, ensure tension measuring devices are used in accordance with the manufacturer's recommendations.
- Before pulling conductors into conduits, ensure proper planning and careful measuring to avoid the slipping of one conductor past another in the conduit. To prevent any damage to insulation that slipping causes, ensure the contractor feeds the various conductors into the conduit in a sequence determined by the length of the individual runs and the use of lubricant as specified. If additional conductors are being installed in an existing conduit, the *Standard Specifications* require that all of the conductors be removed, the conduit cleaned and mandrelled, and the conductors be pulled into the conduit as a unit. Prohibit the slipping of added conductors past existing ones.
- To prevent cutting the conduit, ensure the contractor takes extra care when pulling conductor in plastic conduit. Bushings or pulling bells are required on the ends of conduits.
- Ensure conductors are tagged or labeled according to the specifications. Prohibit the painting of conductors or the use of colored tape on the ends of conductors to obtain the specified insulation colors. The *Standard Specifications* permit the use of phase taping on conductors size 2 and larger.
- Ensure conductor splices are made as shown on the standard detail sheets and as specified. All splices must be tight and waterproof. Conductors size 8 and smaller must be soldered.
- Ensure leads to transformers are spliced as shown on the detail sheet and as specified. A ground clamp fastened to one of the secondary terminals makes an ideal connection for the grounding bond. Ensure transformers are never picked up by the leads.

4-8603F Vehicle Detectors

Along with the controller unit, check the portion of vehicle detectors installed in the controller cabinet. When testing the completed system, include the entire detector system. During installation, the following are some of the duties to perform:

- Verify the loops are laid out in the proper locations.
- Before installing inductive loop detectors, ensure the contractor washes, blows out, and dries all slots cut in pavement. Ensure residue from saw cutting operations is vacuumed from the roadway and disposed of off of the project.
- Ensure that detector loops contain the required conductor type and number of turns and are wound in the specified direction.
- Ensure the contractor splices conductors only at locations permitted under the contract. All splices must be soldered.
- Ensure the contractor places loop wire in the slot with a tool that will not damage the wire's insulation.
- Ensure that loop wires between the loop and adjacent pull box are twisted together as required.
- Observe the placement of loop sealant to ensure the contractor uses the specified material and method of placement.
- When final splicing between loops and lead-in cable is approved, advise the contractor.
- In pull boxes and at the cabinet, ensure the contractor identifies and bands the conductors as specified.

4-8603G Soffit and Wall Luminaires

Ensure soffit lights are installed with the hinge side toward the curb, or as shown on the plans. Also, before pouring concrete around soffits, ensure they are securely fastened. The danger of floating always exists during the pour, and workers frequently will rotate them to place steel or forms. To prevent damaging conduit joints, ensure that conduit between soffit lights is secured and then also supported with concrete blocks. Prohibit standing on conduits or piling material on them.

4-8603H Falsework Lighting

Require the contractor to submit a falsework lighting plan for review and approval by the resident engineer. Ensure the plan conforms to the specifications. Prohibit the contractor from proceeding with work requiring falsework lighting until the plan's approval. The contractor must provide temporary electricity through arrangements with the utility company.

4-8603I Testing

Before completing the work, the contractor must test all traffic signal and lighting circuits in the presence of the resident engineer. The tests are outlined in Section 86-2.14, "Testing," of the *Standard Specifications*. The following tests are to be performed:

- Continuity
- Grounds
- Insulation resistance

- Operational tests
- High voltage tests

The maintenance highway electrician, traffic operations engineers, or construction electrical engineers will aid the resident engineer in observing the test results.

The continuity and test for grounds may be made with an ohmmeter, buzzer and battery combination, or other similar device.

The insulation resistance test is usually made with a megohmmeter, which is a small hand-operated or battery-operated generator, which usually generates about 500 volts. However, prohibit megohmmeter tests on magnetometer sensing elements.

Ensure the contractor tests each circuit of a signal system by applying voltage to it and verifying the lights are operating.

The operational tests consist of a five-day continuous satisfactory operation test for traffic signals and two consecutive nights for lighting systems. If the operation test fails during the five days of operation, repairs will be made and the test will be restarted. If state-furnished material fails, do not restart the test. Once the state-furnished material has been repaired, the test can continue to completion.

4-8603J Completing the Project

To complete the project, do the following:

- Before new work is opened to traffic, ensure all traffic control devices are in place and working properly.
- Until signals are placed in operation, ensure the signal heads are turned away from traffic and completely covered with cardboard boxes or other suitable material.
- Never put into operation a completed traffic signal on a Friday or any day preceding a legal holiday. Also, before the signal is turned on, the traffic operations engineer must be present to adjust the timing in the controller.
- For correct light distribution and minimum glare from luminaires, ensure the contractor positions the luminaires as nearly parallel to the roadway as possible.
- Ensure the contractor has properly installed all signing and striping items.
- To ensure that items that might possibly be overlooked when accepting the work are completed in all their details, prepare for reference a printed checklist similar to the one shown at the end of this section. This checklist should include reminders about the proper positioning of louvers and heads, the placing of the cap on the top of light standards, final painting and cleanup, and similar details.
- Give two weeks notice of the proposed turn-on of the signal system to district traffic operations, public information, signal maintenance, the local fire department, the police department, and schools.

4-8603K Forms

The resident engineer must ensure that all necessary forms are completed or placed in the cabinet. These forms include but are not necessarily limited to the following:

- Notification to the appropriate district units of dates when electrical facilities were placed in service 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 data.
- As-built plan copies to the electrical maintenance unit and to the district traffic unit, the original as-built plans to the district construction office, and one set of field as-built plans and a copy of the special provisions in the controller cabinet.

4-8603L Guaranties

Resident engineers must take the following actions on contracts that include a guaranty for work performed:

- Ensure a notice is installed in each controller cabinet with the following information:
 1. Name, address, and phone number of the contractor, including the phone number of the individual to be notified of any action regarding the guaranty. The contractor referred to here is the one who signed the original guaranty.
 2. Name, address, and phone number of the signal equipment vendor.
 3. Date of the contract acceptance.
 4. Date the guaranty expires.
- Before contract completion, ensure the district maintenance unit is provided with two sets of contract special provisions and project plans.
- Advise the district maintenance unit as soon as possible of the date of contract acceptance.

4-8604 Measurement and Payment

During the course of the project, ensure progress payments are made to the contractor for work completed during the estimate period. The estimate period is from the 21st of one month through the 20th of the next month. For progress payment purposes, keep records of the work completed in each period. One way of keeping track of such work is to mark on a set of contract plans with a felt pen using a different color for different periods. At the 20th of the month, total all the work units performed during that period. Then, using the cost breakdown furnished at the beginning of the project, calculate the value of work completed in this period. To make this a very simple calculation, you can establish a spreadsheet.

On many projects, traffic signal and lighting standards, traffic signal equipment, and electrical hardware items are listed as eligible for payment as material on hand (MOH). On a monthly basis, check the contractor's submittals for MOH, and verify that materials incorporated into the work have been removed from the MOH submittal.

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

4-8604 Measurement and Payment

Example 4-86.1 Example Checklist

(check off if satisfactory)

- 1. Pull boxes to grade _____
- 2. Crosswalks correct _____
- 3. WALK-DON'T WALK heads _____
- 4. Signal Heads louvered properly _____
- 5. Vehicle detector in proper lane _____
- 6. Pull boxes correctly labeled _____
- 7. Correct pedestrian signs at push buttons _____
- 8. Heads correctly positioned _____
- 9. Heads checked for brilliance _____
- 10. Base bolts of poles checked for tightness _____
- 11. Poles checked for proper painting _____
- 12. Ground bushings and connections tight _____
- 13. Proper shield of telephone interconnect in controller box _____
- 14. Tightness of lugs in controller cabinet _____
- 15. Guarantees _____

Inspected by _____

Comments:

