

# Special Specification 6082

## LED Lane Control System



### 1. DESCRIPTION

Furnish and install FTM (Freeway Traffic Management) LED Lane Control Signal (LCS) Field Equipment and all necessary associated electronic devices and hardware in designated field locations and equipment cabinets as shown on the plans, as detailed in accordance with this Special Specification, and as directed by the Engineer.

### 2. MATERIALS

Provide solid state display elements and modules. No mechanical or electromechanical elements or shutters will be accepted. Ensure LCS is suitable for operations in exposed outdoor locations.

- 2.1 **General Requirements.** Provide software to interface with existing equipment and software located in the TransGuide Operations Control Center.
- 2.1.1 Furnish, assemble, fabricate, and install only all new materials that are corrosion resistant and in strict accordance with the details shown on the plans and in the Specifications
- 2.1.2 Furnish and install the following equipment at each LED Lane Control Signal (LCS) field site shown on the plans (includes but is not limited to):
- Lane Control Signals (number as shown on the plans).
  - LCS Controller
  - Cabling, rigid metal conduit and connectors from LCS to controller.
  - LCS Cabinet Foundation with pad
  - Telephone voice communications type line circuit with telephone jack and wall telephone (2554) for voice communication
- 2.2 **Functional Requirements.** Furnish and install LED Lane Control Signals (LCS) on overhead sign bridge structures as shown on the plans. Provide LCS heads capable of being independently controlled to indicate the condition of each lane.
- 2.2.1 Provide LCS heads capable of displaying the following:
- Steady Red X
  - Steady Down Green Arrow
  - Steady Yellow X
  - Steady Down Yellow Arrow
  - Steady Yellow Arrow - Slanted down at 45 degrees right
  - Steady Yellow Arrow - Slanted down at 45 degrees left
- 2.2.2 Provide LCS heads where the signal indication display consists of a group of dots composed of LED's
- 2.2.3 Provide Lane Control Signals driven by an LCS Controller located in an equipment cabinet in the field.
- 2.2.4 Provide Lane Control Signal Controller capable of controlling 8 LCS heads per direction of travel.
- 2.2.5 To assure best visibility of messages in accordance with latest standards, provide certification from an independent laboratory that the LCS meets requirements for uniform size of messages, contrast ratios, minimum and maximum luminance, and chromaticity as listed in the tables below. Perform tests at the 5 ambient light levels listed, where the ambient light is simulated by a Solar Source Simulator in front of the

LCS, and at 10 degrees above the horizontal plane. Measure chromaticity using a Minolta XY-Chroma Meter CS-100. Any LCS head not meeting specifications will be rejected.

2.2.6. Ensure that character's are all the same size in order to have the same visual impact at any given distance.

2.2.7. Calculate contrast ratio as  $Cr = (La - Lb)/Lb$  where:

- Cr = contrast ratio
- La = measured luminance from the message turned on (active) at the proper ambient illumination level
- Lb = measured luminance from the message turned off (inactive) at the proper ambient illumination level.

**Table 1**  
**Contrast Ratio and Luminance Values for Red or Green Messages**

Level	Ambient Illuminance (Lux)	Minimum Contrast Ratio	Minimum Luminance (CD/M <sup>2</sup> )	Maximum Luminance (CD/M <sup>2</sup> )
5	40,000	5	2800	60,000
4	4,000	5	500	10,000
3	400	5	200	2,700
2	40		100	2,000
1	4		60	300

**Table 2**  
**Contrast Ratio and Luminance Values for Yellow Messages**

Level	Ambient Illuminance (Lux)	Minimum Contrast Ratio	Minimum Luminance (CD/M <sup>2</sup> )	Maximum Luminance (CD/M <sup>2</sup> )
5	40,000	10	6,200	120,000
4	4,000	10	1,100	21,000
3	400	10	300	3,700
2	40		200	2,000
1	4		60	300

**Table 3**  
**Color Coordinates**  
**(CIE 1931 Standard Colorimetric System)**

Red	X	0.710	0.700	0.670	0.680
	Y	0.290	0.290	0.320	0.320
Yellow	X	0.618	0.612	0.546	0.560
	Y	0.382	0.382	0.426	0.440
Green	X	0.008	0.284	0.183	0.028
	Y	0.720	0.520	0.359	0.385
White	X	0.440	0.285	0.285	0.440
	Y	0.382	0.264	0.332	0.432

### 3. LANE CONTROL SIGNAL HEAD

3.1. **Physical.** Provide LCS head that uses LED's to display dot matrix indications on a flat, black, non-reflective, square face, with a symbol width and height of 18 in. ± 1/2 in. Form display from individual dots (pixels) of light emitted from LED's.

- 3.2. **Dimming Provision.** Provide LCS head where display can be operated at full brightness during bright ambient light "Day Mode" and with reduced brightness during dim ambient light "Night Mode". Monitor ambient light with a photo-cell mounted in close proximity to the LCS signal head and oriented north or by a method approved by the Engineer.
- Ensure that out of service LED's are automatically reported to the LCS Master and printer or to the notebook maintenance computer provided with the system (if notebook is shown on plans to be provided with system). Ensure that it is possible to determine the status of any LED, in any LCS, from the LCS Master.
- 3.3. **Visibility.** Ensure that the LCS display is clearly visible and legible for 1/4 mile distance within a 20 degree cone centered about the optical axis under normal atmospheric conditions and under any lighting conditions. Visors or hoods must not be necessary for legibility.
- 3.4. **Finish.** Provide an LCS exterior finish of black anodized aluminum or as approved by the Engineer. Painting of any element will not be allowed.

#### 4. LCS CONTROLLER CABINET

- 4.1. **General Composition.** Provide a controller cabinet conforming to and containing the following:
- Outer key lockable protective enclosures.
  - Inner key lockable nonvented enclosure.
  - Microprocessor based controller.
  - Communication interface with DSU.
  - Over-voltage protection device.
  - Power supply and power distribution.
  - LED driver system.
  - Photoelectric controller devices. Fit the cabinet with 2 adjustable threshold electronic devices connected to 1 of the photo-electric sensors located on the LCS which will permit automatic light intensity adjustment dependent on conditions at each LCS location.
  - Internal cabinet lighting. Cabinet is illuminated when outer cabinet door opens and extinguished when closed.
  - Phone Jack with headset. Provide a jack and wall phone (2554) for voice communication at a convenient location inside wall of cabinet.
  - Cabinet and sub-assemblies designed for continuous operation over an outside temperature range of -13°F to +149°F without requiring fans.
  - No forced air cooling required in the cabinet
- 4.2. **Protective Enclosures.** Provide a controller cabinet of the double enclosure type as described below:
- Provide cabinets constructed of unpainted aluminum with a minimum thickness of 0.125 in. Use no wood, wood fiber products, or other flammable material. Make all welds neatly and of a uniform consistency.
  - Completely weatherproof the cabinet to prevent the entry of water. Seal all unwelded seams with a clear or aluminum colored weather-seal compound.
  - Fit the external enclosure with louvers to ensure natural cooling.
  - Provide an inside enclosure that complies with NEMA Type 3S Standard (IEC 55).
  - The internal cabinet dimensions will be submitted by the Contractor and approved by the Engineer; however, provide an internal cabinet whose overall volume does not exceed 20 cu. ft. and which has a height not exceeding 60 in. above the top of the concrete foundation unless approved by the Engineer. Provide a detailed explanation of the theory of operation of the internal/external cabinet design explaining how the configuration will ensure natural heating and cooling.
  - Fit both internal and external enclosures with Corbin 2 lockable access doors. Key the locks alike. Provide all cabinets from the same manufacturer unless otherwise approved by the Engineer.
  - Base mount the external cabinet on a concrete foundation, as detailed on the plans.
  - Mount the transformer supplying power to the lamps inside the external cabinet but outside the internal cabinet enclosure.

4.3. **LCS Controller.** Provide LCS controller that is a software-oriented microprocessor type and has resident software stored in non-volatile memory. Provide LCS controller that is configured in 1 - 19 in. rack mountable chassis and includes the following:

- One inter-PCB (printed circuit board) connection buss, carrying signals and power, onto which all PCBs are connected. Ensure that all PCBs are within the controller chassis and are connected to the buss via card slots.
- Status indicators containing printed circuit boards
- Power supply module
- Central processor module
- LED control module(s)

Incorporation of both the LCS and DMS controller (if plans show a DMS controller at same location) into the same cabinet is permissible if both are constructed by the same manufacturer and if approved by the Engineer.

4.4. **LCS Controller Communication Interface.**

Include in the LCS controller RS-232C/V24 serial interfaces for communication with both the Central Control Computer and the notebook computer.

Provide one EIA RS-232D serial interface to drive asynchronous modems for full duplex communication with the Central Control Computer over dial up lines or on a multi drop network. Switching between dial up and multi drop operation must not require software modification.

Provide a cable for communications between the notebook computer and the second EIA RS-232D serial interface, permanently installed inside the sign controller cabinet, and easily accessible when the cabinet door is open.

For dial-up operation, contractor will acquire and bear the charges of installing and connecting the dial-up telephone line. Provide all needed modems or data service units. The Contractor will pay all phone bills incurred, until system acceptance.

To facilitate system testing, start-up, and on-site maintenance, provide a serial interface port connection for a notebook microcomputer to the LCS controller serial interface which is easily accessible when the cabinet door is open.

4.5. **LCS Controller Functions.** Control the LCS from the Central Control Computer by sending signal to be displayed along with associated parameters to the LCS controller.

4.5.1. The LCS controller and its software must be capable of the following:

4.5.1.1. Display these signals:

- Steady Red X
- Steady Down Green Arrow
- Steady Yellow X
- Steady Down Yellow Arrow
- Steady Yellow Arrow - Slanted down at 45 degrees right
- Steady Yellow Arrow - Slanted down at 45 degrees left

4.5.1.2. Report error and failure messages, including

- Data transmission error
- Receipt of invalid data
- Loss of communications
- LCS sign controller failure

- 4.5.1.3. Monitor messages and status. Transmit a return message to the LCS Master Controller whenever a valid transmission is received. Include the following in the message:
- Address of the LCS controller
  - Indication being displayed
  - Origin of transmission
  - Central/Local switch position

4.5.1.4. Blank any signal displayed in the event of power or LCS controller failure.

4.5.1.5. Direct a test sequence which will exercise each element in the LCS from a notebook computer.

4.5.1.6. Operate without a battery backup system.

4.5.1.7. Fail-safe prevention of improper display in the case of the system malfunction.

Failure of any LCS not directly associated with another LCS or communication line must not affect operation of any other non-associated LCS in the system.

The notebook computer must be capable of providing on-site simulation of all commands.

Provide a battery to record system time when no power is available.

4.6. **LCS Controller Modes of Operation.** The mode of operation determines which level of control governs the LCS selection. The 2 modes of operation are:

- Central - The central control computer or the LCS master controller determines the appropriate display.
- Local - The notebook computer software via the LCS controller determines the appropriate display.

Normally, the LCS controller's mode of operation will be central, allowing the central control computer or the LCS master to select the LCS head indications. When the notebook computer is being used to select the LCS head indications, the mode of operation will be local and the notebook computer's commands honored.

4.7. **Description of the Various LCS Controller Commands.** As a minimum, make available the following commands:

- Display command from the LCS Master Controller.
- Display command from the notebook computer (Local mode).
- LCS Status request, which reports the following:
  - LCS indication
  - Operating mode
  - Mode of the displayed message if any (local/central)
  - Status of the photoelectric sensors
  - Light output level (day/night)
  - LCS number, location, or ID
- LED status request, which provides an instantaneous indication of the status of all the LED's (operational/nonoperational)
- Day/Night switching command
- "Abort" command
- Sign off command (set to blank-out)
- Echo command, which is used to receive from the controller(s) or the master controller the indications currently displayed
- Simulation Mode, where all LCS LED's are off and controller continues to run in simulation mode.

- 4.8. **LCS Controller Communications.** Address the LCS controller with the LCS Master Controller via the communications subsystem.
- 4.8.1. Link the LCS Master Controller RS-232C or RS-232D communication ports with other computers as shown on the plans.
- 4.8.2. Provide each LCS controller with error detection and reporting features to guard against incomplete or inaccurate information transmission. Include:
- Redundancy checking of all data received from the LCS Master Controller, with positive acknowledgement for all transmissions.
  - Status monitoring for communication line malfunction or break.
  - Content validation of all received transmissions for logic or data errors.
- 4.8.3. Provide communication line circuits that are point-to-point or multi-point and have half-duplex asynchronous data transmission at a minimum of 9600 bps, Flow Control: None, Parity: Even, Stop Bit: One.

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## 5. LCS POWER REQUIREMENTS

The LCS Equipment must meet all of its specified requirements when the input power is 115 (+ or -) 20 volts AC, 60 (+ or -) 3 Hz single phase. The maximum power required for each LCS head must not exceed 200 watts. The maximum power required for the controller must not exceed 1,000 watts.

Provide equipment whose operation is not affected by transient voltages, surges and sags normally experienced on commercial power lines. The Contractor is responsible for checking the local power service to determine if a special design is needed for the equipment. The extra costs, if required, will be included in the bid price of this Item.

- 5.1. **Primary Input Power Interruption.** Provide equipment that meets all the requirements in Section 2.1.4 "Power Interruption" of the National Electrical Manufacturers Association (NEMA) Standard TS2 or latest revision.
- 5.2. **Power Service Transients.** Provide equipment that meets the requirements of Section 2.1.6., "Transients, Power Service" of the NEMA Standard TS2 or latest revision.
- 5.3. **Wiring.** All wiring must meet the requirements of the National Electrical Code. Cut all wires to proper length before assembly. Do not double back any wire to take up slack. Neatly lace wires into cables with nylon lacing or plastic straps. Secure cables with clamps. Provide sufficient cable slack to facilitate removal and replacement of assemblies, panels, and modules.
- Supply and install under this Item all wiring necessary to interconnect the LCS load switches in the field cabinet and the LCS heads. If additional wires are required, the Contractor will install them at no additional cost. Provide wiring and interface equipment for interconnecting the controller and the multiplexers by using NEMA-type inputs and outputs.
- 5.4. **Grounding.** Ensure that the LCS support bracket and equipment Cabinet are grounded according to the NEC or as shown on plans.
- 5.5. **Transient Suppression.** Provide DC relays, solenoids and holding coils that have diodes across the coils for transient suppression. Provide AC Contactors that have snubbers.
- 5.6. **Power Service Protection.** Provide equipment that contains readily accessible, manually resettable or replaceable circuit protection devices (such as circuit breakers or fuses) for equipment and power source protection.

Provide circuit breakers or fuses that are sized so that no wire, component, connector, PC board or assembly is subjected to sustained current in excess of their respective design limits upon the failure of any single circuit element or wiring.

Ensure that a power failure of less than one cycle (micro-failures) has no effect on the sign display.

Ensure that a power failure of more than one cycle results in the following:

- Extinguishing of the sign LED's
- Saving of all the parameters including the current display in CMOS protected RAM
- Shutdown of the controller
- Updating of the current date, time, and remaining display time using an internal battery.

At power recovery, the controller must resume the original display, duration time permitting, and report the power failure and power recovery date and time to the LCS Master.

- 5.7. **Fail Safe.** Provide equipment that is designed so that it's failure will not cause the failure of any other unit of equipment.

## 6. MECHANICAL REQUIREMENTS

- 6.1. **LCS Head.** Provide LCS heads conforming to the following:

- LCS face measures 30 in. x 30 in. ( $\pm 5\%$ ). Provide a case made of sheet aluminum with a minimum thickness of 0.125 in. The exterior of each LCS head must be Black Anodized Aluminum. Paint all brackets, anchor bolts, and conduit runs attached to the surface of the bridge or sign structure the same color as the bridge beam or truss. (All painting is subsidiary to related Items.)
- Provide a signal and lens mount with a black front panel to minimize legibility when the signal is not illuminated. Ensure that absolutely no color appears in the lens when not illuminated, regardless of sunlight intensity.
- Provide a barrier type terminal strip in the signal for the connection of field wires. Clearly mark the function of each terminal.
- Mount all LED'S on a vertically hinged door which opens to the side. Make all components readily accessible when the door is opened, with the only tool required for maintenance or replacement of components a standard screwdriver.
- Provide doors that can be opened and secured by maintenance personnel (without tools) using 2 lockable clasps mounted on the door. Provide a sliding restraint bar with an automatic stop in the open position mounted between the door and the housing to keep the door from twisting and limit the amount of door travel in high winds.
- Ensure that the signal housing case, together with door and mounting attachments, comprises a dust and moisture proof housing for the optical unit, connecting wiring, and terminal block. Provide signal housing and door, fittings, and accessories that are noncorrosive, rust resistant and capable of withstanding constant exposure to sunlight and corrosive atmospheres. Ensure that materials are of adequate strength for the purpose utilized. Ensure that the LED socket is designed so as to preclude the formation of corrosion on either the LED or socket contacts and so that the LED's do not work loose from the socket when vibrated.
- Ensure that the LCS head is able to withstand 120 mph wind loading without any damage or loosening from structure.
- Provide a housing that is NEMA 4 rated with the door internally gasketed to provide the necessary seal and with all corners welded for stability and water tightness. Do not use silicone or other sealants to seal joints. Install one screened vent on either side of the LCS for ventilation, and 1 threaded brass liquid tight fitting (bushing) on the back of the LCS for securing the field cables and sealing the cable opening.
- Provide an LCS with a front that is completely finished in matte black. To eliminate any distractions to the illuminated messages, shiny, reflective or non-black areas must not be visible from the front of the LCS (including door locks). To avoid corrosion or dirt entry, mount the door hinge internal to the housing. Front faces of any sort (plastic, Lexan, etc.) will not be allowed.

- Mount two 1-1/2 in. aluminum hubs onto the rear of the housing to allow for connection to pipe nipples or other mounting hardware provided by others. Ensure that the inside area of the housing is substantially reinforced at the point where the hubs are mounted to prevent fatigue cracks.
- In order to enhance the readability of the display in back-lit conditions, the display must be surrounded by a flat black area. The outside dimensions of each LCS head must be 30 in. x 30 in. ( $\pm 5\%$ ).

6.2. **Modular Design.** Provide equipment that is modular in design so that major components may be easily replaced in the field. Ensure that modules of unlike function are mechanically keyed to prevent insertion into the wrong socket or connector.

Clearly identify all modules and assemblies with name, model number, serial number and any other pertinent information required to facilitate equipment maintenance.

6.3. **Connectors and Harness.** Make all external connections with connectors. Key the connectors to preclude improper hookups.

Color code and/or appropriately mark all wires to and from the connectors. Ensure that all connectors are coated with a minimum of 50 microns of gold.

6.4. **Design Requirements.** Ensure that the LCS equipment meets all of the specified requirements during and after subjection to any combination of the following:

6.4.1. Environmental.

- Ambient temperature range of  $-30^{\circ}\text{F}$  to  $+165^{\circ}\text{F}$
- Temperature shock not to exceed  $30^{\circ}\text{F}$  per hour, during which the relative humidity does not exceed 95%
- Relative humidity range not to exceed 95% over the temperature range of  $40^{\circ}\text{F}$  to  $110^{\circ}\text{F}$
- Moisture condensation on all surfaces caused by temperature changes
- Exposure to a temperature and relative humidity of  $158^{\circ}\text{F}$  and 22% respectively. Maintain the equipment at this condition for 48 hours. At the conclusion of the 48-hour period, the equipment must meet the requirements of the Prototype Approval Tests within 30 minutes of beginning the test.

6.4.2. **Primary Power Variation.** The equipment must meet specified performance requirements when the input voltage is plus or minus 20 volts from the nominal value of 115 volts. Operate the equipment at the extreme limits for at least 15 minutes, and ensure that passes the Prototype Approval Tests.

6.4.3. **High Frequency.** The equipment must meet the requirements of the Prototype Approval Tests when subjected to the high-frequency and voltage transient interference specified in the Testing Requirements section of this Specification.

6.4.4. **Vibration.** The equipment must show no degradation of mechanical structure, soldered components, plug-in components or satisfactory operation in accordance with the manufacturer's equipment specifications after being subjected to the following vibration test:

Secure the LCS head device to a shaker head of suitable electro-mechanical shaker in the vertical, lateral and longitudinal planes. The object of the test is to vibrate the device in each of the three mutually perpendicular axes, in accordance with the following levels and/or parameters:

- Amplitude - 0.06 in. Double Amplitude (peak to peak)
- Linear Acceleration (g's) - 0.5 maximum
- Linear Velocity - approximately 7.4 in. per second
- Frequency - 40 Hz
- Duration - Five minute dwell in each axis

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## 7. PORTABLE NOTEBOOK COMPUTER

If shown in the plans, provide a battery powered portable computer in conformance with Special Specification, "Portable Notebook Microcomputer", for local control in the event of an LCS Master Controller communication link failure and for remote operation. Ensure that the portable computer with its software can perform the following functions:

- LCS startup
- Display any combination of LCS head indications, including any symbol stored in the LCS controller EEPROM or RAM
- Create and download symbols to be stored in EEPROM.
- Create a non-volatile activity log, for later transfer to the LCS Master Controller, in order to maintain a complete historical record if the Master Controller is unable to do so
- Dial-in to LCS Master Controller and provide remote access to all LCS Master functions
- All maintenance diagnostics and provisioning
- Remote Terminal functions
- Start a "test pattern" display to check and verify each individual element of the LCS
- Create and modify the controller's configuration without having to download/import an external file
- Record and view poll cycles

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## 8. CONSTRUCTION

- 8.1. **General.** For equipment design and construction, utilize the latest available techniques with a minimum number of different parts, subassemblies, circuits, cards and modules in order to maximize standardization and commonality.

Provide equipment designed for ease of maintenance. Make all component parts readily accessible for inspection and maintenance. Ensure that the only tools and test instruments required for maintenance are simple hand held tools, basic meters and oscilloscopes. Provide test points for checking essential voltages and waveforms.

- 8.2. **Electronic Components.** Ensure that all electronic components comply with the Special Specification, "Electronic Components".

- 8.3. **Mechanical Components.** Ensure that all external screws, nuts and locking washers are stainless steel. Do not use self-tapping screws unless specifically approved by the Engineer. Provide only parts made of corrosion resistant material, such as plastic, stainless steel, aluminum or brass. Protect all materials used in construction from fungus growth and moisture deterioration.

Separate dissimilar metals with an inert dielectric material.

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## 9. DOCUMENTATION REQUIREMENTS

Provide five complete sets of operation and maintenance manuals which, at a minimum, include the following:

- Complete and accurate schematic diagrams
- Complete installation procedures
- Complete performance specifications (functional, electrical, mechanical and environmental)
- Complete parts list including names of vendors for parts not identified by universal part numbers such as JEDEC, RETMA or EIA
- Pictorial of components layout on circuit board
- Complete maintenance and trouble-shooting procedures
- Complete stage-by-stage explanation of circuit theory and operation.

## 10. TESTING REQUIREMENTS

It is the practice of the Texas Department of Transportation to require performance testing of all materials and equipment not previously tested and approved. If technical data is not considered adequate for approval, samples may be requested for testing by the Engineer. Contract period will not be extended for time lost or delays caused by testing prior to final Texas Department of Transportation approval of any materials and/or equipment.

Unless otherwise specified, the Contractor is responsible for satisfying all inspection requirements prior to submission for the Engineer's inspection and acceptance. The Engineer reserves the right to witness all demonstration and stand-alone tests.

Compare the results of each test with the requirements specified herein. Failure to conform to the requirements of any test will be counted as a defect, and the equipment will be subject to rejection by the Engineer. Rejected equipment may be offered again for retest provided all noncompliances have been corrected and retested by the Contractor and evidence thereof submitted to the Engineer.

The tests on all of 1 type of equipment must be completed within 5 days and any delays in performing all these tests will result in the Contractor paying the additional costs of providing the Engineer's representatives for the additional testing.

Final inspection and acceptance of equipment will be made after installation at the destination specified, unless otherwise specified herein.

- 10.1. **Test Procedures.** Provide 5 copies of all Prototype approval, Stand-Alone, and system test procedures and data forms to the Engineer for approval at least 60 days prior to the day the tests are to begin. Include in the test procedures the sequence in which the tests will be conducted. The test procedures must have the Engineer's approval prior to submission of equipment for tests. Furnish data forms containing all of the data taken, as well as quantitative results for all tests. Have the data forms signed by an authorized representative (company official) of the equipment manufacturer. Provide at least 1 copy of the data forms to the Engineer.
- 10.2. **Prototype Approval Tests.** Conduct Prototype Approval Tests in the State of Texas and as approved by the Engineer on 1 or more samples of equipment of each type, to determine if the design of the equipment meets the requirements of this specification. Conduct all tests in accordance with the approved test procedures as described in these specifications. Notify the Engineer a minimum of 25 working days in advance of the time when these tests are to be conducted.
- 10.2.1. **Temperature and Condensation.** Perform the following tests on the field equipment in the order specified below:
- Stabilize the equipment at 0°F. After stabilization at this temperature, operate the equipment without any performance degradation for 2 hours.
  - Cause moisture to condense on the equipment by allowing it to warm up to room temperature in an atmosphere having relative humidity of at least 40%. Operate the equipment without any performance degradation for 2 hours while wet.
  - Stabilize the equipment at 140°F. After stabilization at this temperature, operate the equipment without any performance degradation for 2 hours.
- 10.2.2. **Primary Power Variation.** Meet the specified performance requirements when the equipment is subject to input voltage that is plus or minus 20 volts from the nominal value of 115 volts. Operate the equipment successfully at the extreme limits for at least 15 minutes.
- 10.2.3. **Relative Humidity.** Meet the specified performance requirements when the equipment is subjected to a temperature and relative humidity of 140°F and 40% respectively. Maintain the equipment at the above condition for 48 hours. At the conclusion of the 48 hour soak, ensure that the equipment meets specified performance requirements.

- 10.2.4. **High-Frequency.** Meet the specified performance requirements when subjected to high-frequency and voltage transient interference specified in Section 2.1.6., "Transient, Power Service" of the NEMA standard TS1-1989 or latest revision.
- 10.2.5. **Vibration.** Provide equipment that shows no degradation of mechanical structure, soldered components, plug-in components, or satisfactory operation in accordance with the manufacturer's equipment specifications after being subjected to the vibration tests as described in Section 2.2.5., "Vibration Test" of the NEMA standard TS1-1989 or latest revision.
- 10.2.6. **Consequences of Prototype Approval Test Failure.** Conduct Prototype Approval Tests on units randomly selected from the prototype design manufacturing run, or if only 1 design prototype is manufactured, on that unit. If the unit fails the Prototype Approval Test, correct the design fault and repeat the entire Prototype Approval Test. Modify all deliverable units without additional costs to the State to include design changes required to pass the Prototype Approval Tests.
- 10.3. **Stand-Alone Tests.** Conduct an approved Stand-Alone Test of the equipment installation at the field site. As a minimum, exercise all stand-alone functional operations of the field equipment with all of the equipment installed per the plans or as directed by the Engineer.
- Complete the approved data forms and give to the Engineer for review to determine acceptance or rejection of equipment. Provide at least 5 working days notice prior to all tests to permit the Engineer or his representative the ability to observe each test.
- Correct any units that fail the stand-alone test or replace them with other units and repeat test until units successfully pass test.
- Prepare and deliver to the Engineer a report detailing any modifications made to a unit as a result of a stand-alone test failure. Describe the nature of the failure and the corrective action taken. If a failure pattern, as defined by the Engineer, develops, the Engineer may direct that design and construction modifications be made to all units without additional cost or extension of the contract period.
- 10.4. **System Tests.** Conduct an approved LCS system test on the field equipment with the central equipment. At a minimum, exercise all remote control functions and display the return status codes from the controller for a minimum of 72 hours. Complete approved data forms and turn over to the Engineer for review to determine acceptance or rejection of equipment.
- Correct any units or components in the subsystem that fail the system test or replace them with other units or components and repeat test until units successfully pass test.
- Prepare and deliver to the Engineer a report detailing any modifications made to a unit as a result of a system test failure. Describe the nature of the failure and the corrective action taken.

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## 11. LCS CABINET FOUNDATION

Furnish and install the cabinet foundation with pad as shown on the plans and in accordance with Item 656.

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## 12. EXPERIENCE REQUIREMENTS

Contractor or subcontractor involved in the installation and testing of the Lane Control Signal System must meet the following requirements:

- Two years experience in the manufacturing, installation and testing of LED Lane Control Signal systems.
- Two installed systems where LED Lane Control Signal systems (as described in this specification and as shown in the plans) have been in continuous satisfactory operation for at least 1 year. Submit as proof, photographs or other supporting documents, and the names, addresses and telephone numbers of the operating personnel who can be contacted regarding the systems.

- One LED Lane Control Signal system (which may be 1 of the 2 in the preceding paragraph) which the Contractor can arrange for demonstration to the Engineer.

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**13. WARRANTY**

Guarantee that equipment furnished and installed for this project will perform according to the manufacturer's published specifications. Warrant equipment against defects and/or failure in design, materials and workmanship in accordance with the manufacturer's standard warranty. Assign to the Department all manufacturer's normal warranties or guarantees on all electronic, electrical, and mechanical equipment, materials, technical data, and products furnished and installed on the project. Repair or replace defective equipment, at the manufacturer's option, during the warranty period at no cost to the Department.

Provide equipment with 95% of the manufacturer's standard warranty remaining on the date that equipment invoices are submitted by the Contractor for payment. Equipment with less than 95% of its warranty remaining will not be accepted by the Department.

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**14. MEASUREMENT**

- LED Lane Control System will be measured as each LED Lane Control System unit furnished, installed, made fully operational, and tested in accordance with these Special Specifications or as directed by the Engineer.
- LCS Cabinet Foundation will be measured as each unit furnished and installed.

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**15. PAYMENT**

The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "LED Lane Control System" and "LCS Cabinet Foundation". This price will include all equipment with all cables and connectors, all documentation and testing, all concrete, reinforcing steel, anchor bolts, and conduit and will also include the cost of furnishing all labor, materials, software training, equipment, and incidentals.