

**9-29 ILLUMINATION, SIGNAL, ELECTRICAL****9-29.1 Conduit, Innerduct, and Outerduct**

Rigid metal conduit, liquidtight flexible metal conduit, and associated couplings and connectors shall conform to National Electrical Code. PVC conduit shall conform to National Electrical Code and to NEMA Specification TC-2 (Conduit), TC-3 (Fittings-UL 514), and UL 651 (standard for rigid nonmetallic conduit). Fiberglass conduit and fittings shall be UL listed and shall comply with ANSI/NEMA standards TC-14A (filament wound reinforced thermosetting resin conduit and fittings) and ASTM D-2996.

Exterior and interior surfaces of all steel conduit, except threaded ends, shall be uniformly and adequately zinc coated by a hot-dip galvanizing process. The average weight of zinc coating shall be not less than 0.80 ounces of zinc per square foot of single surface area as determined by tests on 12-inch samples taken from each end of a standard length of conduit of each size. The weight of zinc coating on any individual test Specifications shall be not less than 0.70 ounces of zinc per square foot of single surface area. The weight of zinc coating will be determined in accordance with AASHTO T 65. Determinations and nominal weights shall conform to the requirements of the Underwriters Laboratory (latest edition). In addition, the exterior as well as the interior conduit samples shall withstand four dips in the PREECE test in accordance with ASTM A 239.

Couplings for rigid metal type conduits may be either hot-dip or electroplated galvanized.

Grounding end bushings shall comply with the following:

1. Full standard threads, around the entire 360 degree circumference.
2. Malleable iron material.
3. Hot-dip galvanized, per AASHTO M 111.
4. Copper, tinned copper, stainless steel or integral lug.
5. Stainless steel clamping screw, mounting screw and set screw.

Every length of rigid metal conduit shall bear the label of Underwriters Laboratories, Inc. or the label of the Canadian Standards Association if affected items of Canadian manufacture are approved for use on the project. Installation shall conform to appropriate articles of the Code.

Conduit bodies and fittings for rigid steel conduit systems shall be UL/CSA listed for wet locations, hot dip galvanized malleable iron. Conduit bodies shall have tapered threads, and include a bolt on cover with stainless steel screws and a neoprene gasket seal against moisture.

Liquidtight flexible metal conduit shall consist of single strip continuous flexible interlocked steel galvanized inside and out forming a smooth internal wiring channel with a liquid tight covering of sunlight resistant flexible polyvinyl chloride. Liquid-tight connectors shall be UL/CSA listed for wet locations, insulated throat type.

Conduit clamps shall be two hole type straps, stainless steel or hot dip galvanized, except in marine environments, where Type 316 stainless steel shall be used.

Conduit supports for surface mounted conduit shall be hot dipped galvanized or Type 304 stainless steel channel type using Type 304 stainless steel bolts and spring nuts. Type 316 stainless steel shall be used in marine and other highly corrosive environments.

All types of conduit shall be free from defects, including out of round, foreign inclusions, etc. Conduit shall be uniform in color, density, and physical properties.

Conduit shall be straight and the ends shall be cut square to the inside diameter. All conduit shall display the Underwriters Laboratory certification (UL Listed).

PVC solvent cement shall meet ASTM D 2564 including note 8 (label to show pipe sizes for which the cement is recommended).

Drilling fluid used for directional boring shall be inert mixture of water and bentonite clay, conforming to the drilling equipment manufacturers recommendations.

Rigid galvanized steel conduit is required for all surface mounted conduit, with the exception of Electrical service utility poles, upon the approval of the serving Utility company only.

Galvanized steel conduit outerduct shall be hot-dipped galvanized inside and out. The conduit shall be smooth and free from burrs. Conduit shall be supplied and shipped with thread protectors.

#### **Expansion, and Deflection Fittings**

Expansion fittings for rigid galvanized steel conduit shall be weather tight, with hot dipped galvanized malleable or ductile iron end couplings and body and shall allow for 4-inches of movement minimum (2-inches in each direction). Expansion fittings for rigid galvanized steel conduit shall have an external tinned copper bonding jumper. As an alternative to the external tinned copper bonding jumper, an expansion fitting with an internal tinned copper bonding jumper may be used. The internal tinned copper bonding jumper shall not reduce the conduit conductor capacity.

Expansion fittings for rigid galvanized steel conduit outerduct with innerduct shall be weather tight, with hot dipped galvanized ductile iron or bronze end couplings, with molded neoprene sleeve and internal tinned copper bonding jumper and shall allow for 8-inches of movement (4-inches in each direction) minimum.

Deflection fittings for rigid galvanized steel conduit shall be weather tight, with hot dipped galvanized ductile iron or bronze end couplings, with molded neoprene sleeve, stainless steel bands and internal tinned copper bonding jumper. Deflection fittings shall provide for conduit movement of  $\frac{3}{4}$ -inch, in all directions and angular movement of 30 degree in any direction.

A combination deflection and expansion fitting for rigid galvanized steel conduit shall be made from a deflection fitting and an expansion fitting as listed above, with the addition of an external tinned copper bonding jumper. The external tinned copper bonding jumper shall be of sufficient length to be installed on the conduit run and bypass the combination deflection/expansion fitting. As an alternative to the external tinned copper bonding jumper that is installed to bypass the combination deflection/expansion fitting, an expansion fitting with an internal tinned copper bonding jumper may be used. The internal tinned copper bonding jumper shall not reduce the conduit conductor capacity. This combination deflection and expansion fitting shall be installed as noted in the plans.

All rigid galvanized steel conduits attached to bridges shall be equipped with expansion fittings placed on alignment with bridge expansion joints and approximately parallel to the longitudinal movement of the bridge. A deflection fitting shall be placed at each conduit transition from bridge attachment to the underground section.

PVC Outerduct with innerduct and PVC conduit shall have a combination deflection and expansion fitting (as described above) placed at each conduit transition from bridge attachment to the underground section. The external tinned copper bonding jumper may be omitted on PVC outerduct with innerduct and PVC conduit.

The coupling body for the innerduct shall be factory assembled in the bell end of the outerduct and shall be manufactured from a high impact engineered thermoplastic. The coupling body face shall be supplied with lead-ins to facilitate assembly.

#### **Inner and Outer duct**

Each section of steel outerduct shall be supplied with one reversing spin coupling that allows straight sections and fittings to be joined without spinning the conduit. The reversing coupling shall be galvanized and have three setscrews or a lock nut ring to lock the coupling in place. Setscrews or lock nut ring shall be corrosion resistant and insure continuous electrical ground. The coupling shall be galvanized steel with the same material properties as the conduit.

The innerduct system shall be factory-installed and shall be designed so that expansion and contraction of the innerducts takes place in the coupling body to eliminate compatibility problems.

The conduit coupling body shall have a factory-assembled gasket that is multi-stage and anti-reversing, sealing both the outerduct and innerducts. A secondary mid body O-ring gasket shall be seated into the coupling body and shall hold the coupling body firmly in the steel outerduct.

The conduit system shall be designed so that assembly of components can be accomplished in the following steps:

1. Loosen setscrews or lock nut ring on coupling and spin back to allow for insertion.
2. Spin coupling mating sections forward to bottom.
3. Tighten set screws on lock nut ring.

#### **Innerduct for Straight Sections of PVC and Rigid Galvanized Steel Conduits**

The 4-inch PVC outerduct shall be equipped with four innerducts. The innerducts shall have a minimum outside diameter of 1¼-inch a minimum inside diameter of 1½-inch. Larger diameter innerducts may be provided if the wall thickness and diameter tolerances are met. The tolerance for inside and outside diameters shall be 0.0005-inch. The innerducts shall have a minimum wall thickness of 0.006-inch. Innerduct shall be color coded. The color coding shall be three gray and one white. Alternate color codes are permitted as long as the color codes are contiguous between adjacent junction boxes. The innerducts shall be factory installed in the outerduct.

Dynamic coefficient of friction of innerducts shall be tested in accordance with Telcordia GR-356-CORE procedure. The coefficient of friction shall be less than 0.30 between medium density polyethylene jacketed fiber optic cable and the prelubricated innerduct. The coefficient of friction shall be less than 0.10 between the ¼-inch diameter polypropylene rope (suitable for fiber optic cable pulling) and the prelubricated innerduct. Pull rope used for testing (meeting the 0.10 coefficient of friction requirement) shall be the same type as the pull rope used for cable installation. The Contractor shall provide, as part of the conduit submittals, a certificate of compliance with Section 1-06.3 stating that the conduit meets the coefficient of friction requirements detailed above.

The innerduct shall have a smooth, non-ribbed interior surface, with a factory prelubricated coating. The coating shall provide the required dynamic coefficient of friction.

Innerduct shall be extruded polyvinyl chloride (PVC) or polyethylene (PE).

#### **PVC Outerduct**

Protective outerduct for PVC schedule 40 and PVC schedule 80 conduit outerduct shall be 4-inch with a minimum 5-inch extended integral "bell end" and shall be gray in color. The outerduct minimum wall thickness shall be 0.23-inch for Schedule 40 PVC and 0.32-inch for Schedule 80 PVC.

Conduit and fittings for PVC outerduct shall be supplied with an ultraviolet inhibitor.

The coupling body for PVC outerduct shall include a factory-assembled, multi-stage gasket that is anti-reversing, sealing both the outer and innerducts. A secondary mid body gasket shall be seated at the shoulder of the bell to assure air and water integrity of the system. The bell end and the coupling body assembly shall accept a minimum of 5-inches of the spigot end.

The conduit system shall be designed so that straight sections and fittings will assemble without the need for lubricants or cement.

#### **Bends for 4-inch PVC Conduit with Innerducts**

All bend radii shall be 36-inches or greater. The conduit system shall provide a complete line of fixed and flexible sweeps with system compatible bell and spigot ends. The bends shall contain high-temperature burn-through-resistant innerducts manufactured from PVC, PE, or Nylon-66. The innerducts shall meet all other requirements for innerduct per Innerduct for Straight Sections of PVC Conduits.

#### **Prefabricated fixed Bends (for Innerducts)**

The prefabricated standard fixed PVC bends provided shall have a radius between 4-feet and 9-feet and sweep angles of 11.25 degree, 22.5 degree, 45 degree, or 90 degree.

Direction changes shall not exceed 90 degree.

Flexible bends shall be supplied in two lengths to meet field requirements. Conduit lengths shall be 10-feet 6-inches and 16-feet 6-inches. These conduits may be field bent to a uniform radius no less than 4-feet. The field bend shall be no greater than 90 degree. Grounding shall be continuous in flexible bends. Outerduct for flexible bends shall be manufactured from reinforced PVC.

All outerduct shall be marked with data traceable to plant location.

PVC outerduct shall have a longitudinal print-line that denotes "Install This Side Up" for proper innerduct alignment. PVC outer-ducts shall have a circumferential ring on the spigot end of duct to provide a reference point for ensuring the proper insertion depth when connecting conduit ends. The line shall be a minimum of 5-inches from the end of the conduit.

All fittings, adapters, and bends (sweeps) shall be provided and shall be manufactured from the same materials and manufacturing process as the conduit, except as specified otherwise. The conduit system shall be a complete system with the following accessories:

- Manhole Terminator Kits
- Deflection Fittings
- Offset Fittings
- Expansion/Contraction Fittings
- Repair Kits
- Conduit and Innerduct Plugs
- Pull string
- Pull rope

Conduit spacers

Split internal expansion plugs shall be supplied to suit various cable sizes. Duct plugs shall be polypropylene and be equipped with a neoprene or polyurethane gasket. Plugs shall be equipped with an attachment to secure the pull rope in the innerduct. The plug shall withstand 5 psi.

Steel casing material shall conform to ASTM A 252 Grade 1, 2, or 3 or casing as approved by the engineer. The Contractor shall furnish pipe of adequate thickness to withstand the forces exerted by the boring operation as well as those forces exerted by the earth during installation and shall be a minimum of  $\frac{3}{8}$ -inch thick.

All joints shall be welded by a qualified welder. Qualified in accordance with AWS D1.1 structural welding code, section 3, workmanship.

## **9-29.2 Junction Boxes, Cable Vaults and Pull Boxes**

### **9-29.2(1) Standard Duty and Heavy Duty Junction Boxes**

For the purposes of this Specification concrete is defined as Portland Cement Concrete and non-concrete is all others.

Standard Duty Junction Boxes are defined as Type 1, 2, 7 and 8, and Heavy Duty Junction Boxes are defined as Type 4, 5, and 6.

The Contractor shall provide shop drawings if their manufacturing process or standard production model includes any deviation from the Standard Plan. For each type of junction box, or whenever there is a design change to the junction box, a proof test, as defined in this Specification, shall be performed once in the presence of the Engineer.

#### **9-29.2(1)A Standard Duty Junction Boxes**

All Standard Duty Junction Boxes shall have a minimum load rating of 22,500 pounds and be tested in accordance with 9-29.2(1)C. A complete Type 7 or Type 8 Junction Box includes the spread footing shown in the Standard Plans.

##### **Concrete Junction Boxes**

The Standard Duty Concrete Junction Box steel frame, lid support, and lid shall be painted with a black paint containing rust inhibitors or painted with a shop applied, inorganic zinc primer in accordance with Section 6-07.3, or hot dip galvanized in accordance with ASTM A 111.

Concrete used in Standard Duty Junction Boxes shall have a minimum compressive strength of 6000 psi when reinforced with a welded wire hoop, or 4000 psi when reinforced with welded wire fabric or fiber reinforcement. The frame shall be anchored to the box by welding the wire fabric to the frame or by welding headed studs  $\frac{3}{8}$  inch x 3 inches long, as specified in section 9-06.15, to the frame. The wire fabric shall be attached to the studs and frame with standard tie practices. The box shall contain ten studs located near the centerline of the frame and box wall. The studs shall be placed one anchor in each corner, one at the middle of each width and two equally spaced on each length of the box.

Material for Type 1, 2, 7 and 8 Concrete Junction Boxes shall conform to the following:

Concrete	Section 6-02
Reinforcing Steel	Section 9-07
Fiber Reinforcing	ASTM C 1116, Type III
Lid	ASTM A786 diamond plate steel
Frame	ASTM A786 diamond plate steel or ASTM A36 flat steel
Lid Support & Handle	ASTM A36 steel
Anchors (studs)	Section 9-06.15

#### **Non-concrete Junction Boxes**

Material for the non-concrete junction boxes shall be of a quality that will provide for a similar life expectancy as Portland Cement Concrete in a direct burial application.

Type 1, 2, 7, and 8 non-concrete junction boxes shall have a Design Load of 22,500 lbs. and shall be tested in accordance with 9-29.2(1)C. Non-concrete junction boxes shall be gray in color and have an open bottom design with approximately the same inside dimensions, and present a load to the bearing surface that is less than or equal to the loading presented by the concrete junction boxes shown in the Standard Plans. Non-concrete junction box lids shall include a pull slot and shall be secured with two ½ inch stainless steel hex-head bolts factory coated with anti-seize compound and recessed into the cover. The tapped holes for the securing bolts shall extend completely through the box to prevent accumulation of debris. Bolts shall conform to ASTM F 593, stainless steel.

#### **9-29.2(1)B Heavy Duty Junction Boxes**

Heavy Duty Junction Boxes shall be concrete and have a minimum vertical load rating of 46,000 pounds without permanent deformation and 60,000 pounds without failure when tested in accordance with 9-29.2(1)C.

The Heavy Duty Junction Box steel frame, lid support and lid shall be painted with a shop applied, inorganic zinc primer in accordance with Section 6-07.3.

The concrete used in Heavy Duty Junction Boxes shall have a minimum compressive strength of 4000 psi.

Material for Type 4, 5, and 6 Concrete Junction Boxes shall conform to the following:

Concrete	Section 6-02
Reinforcing Steel	Section 9-07
Lid	ASTM A786 diamond plate steel, rolled from plate complying with ASTM A572, grade 50 or ASTM A588 with min. CVN toughness of 20 ft-lb at 40 degrees F.
Frame and stiffener plates	ASTM A572 grade 50 or ASTM A588, both with min. CVN toughness of 20 ft-lb at 40 degrees F
Handle	ASTM A36 steel
Anchors (studs)	Section 9-06.15
Bolts, Nuts, Washers	ASTM F 593 or A 193, type 304 or 316

The lid stiffener plates shall bear on the frame, and be milled so that there is full even contact, around the perimeter, between the bearing seat and lid stiffener plates, after fabrication of the frame and lid. The bearing seat and lid perimeter bar shall be free from burrs, dirt and other foreign debris that would prevent solid seating. Bolts and nuts shall be liberally coated with anti-seize compound. Bolts shall be installed snug tight. The bearing seat and lid perimeter bar shall be machined to allow a minimum of 75% of the bearing areas to be seated with a tolerance of 0.0 to 0.005 inches measured with a feeler gage. The bearing area percentage will be measured for each side of the lid as it bears on the frame.

#### **9-29.2(1)C Testing Requirements**

Junction boxes shall be tested by an independent materials testing facility, and a test report issued documenting the results of the tests performed.

For concrete junction boxes the independent testing lab shall meet the requirements of AASHTO R 18 for Qualified Tester and Verified Test Equipment. The test shall be conducted in the presence of and signed off by the Engineer or a designated representative. The Contractor shall give the Engineer 30 days notice prior to testing. One copy of the test report shall be furnished to the Contracting Agency certifying that the box and cover meet or exceed the loading requirements for a concrete junction box, and shall include the following information:

1. Product identification.
2. Date of testing.
3. Description of testing apparatus and procedure.
4. All load deflection and failure data.
5. Weight of box and cover tested.
6. Upon completion of the required test(s) the box shall be loaded to failure.
7. A brief description of type and location of failure.

For non-concrete junction boxes the testing facility shall be a Nationally Recognized Testing Laboratory (witnessing is not required). One copy of the test report shall be furnished to the Contracting Agency certifying that the box and cover meet or exceed the loading requirements for a non-concrete junction box, and shall include the following information:

1. Product identification.
2. Date of testing.
3. Description of testing apparatus and procedure.
4. All load deflection data.
5. Weight of box and cover tested.

#### **Testing for Standard Duty Concrete Junction Boxes**

Standard Duty Concrete Junction Boxes shall be load tested to 22,500 pounds. The test load shall be applied uniformly through a 10-inch x 10inch x 1 inch steel plate centered on the lid. The test load shall be applied and released ten times, and the deflection at the test load and released state shall be recorded for each interval. At each interval the junction box shall be inspected for lid deformation, failure of the lid/frame welds, vertical and horizontal displacement of the lid/frame, cracks, and concrete spalling.

Concrete junction boxes will be considered to have withstood the test if none of the following conditions are exhibited:

1. Permanent deformation of the lid or any impairment to the function of the lid.
2. Vertical or horizontal displacement of the lid frame.
3. Cracks wider than 0.012 inches that extend 12 inches or more.
4. Fracture or cracks passing through the entire thickness of the concrete.
5. Spalling of the concrete.

#### **Testing for the Standard Duty non-concrete Junction Boxes**

Non-concrete Junction Boxes shall be tested to a minimum of 22,500 lbs as defined in the ANSI/SCTE 77-2002 Tier 15 test method. In addition the Contractor shall provide a Manufacture Certificate of Compliance for each non-concrete junction box installed.

#### **Testing for Heavy Duty Junction Boxes**

Heavy Duty Junction Boxes shall be load tested to 46,000 pounds. The test load shall be applied vertically through a 10-inch x 20-inch x 1-inch steel plate centered on the lid with an orientation both on the long axis and the short axis of the junction box. The test load shall be applied and released ten times on each axis. The deflection at the test load and released state shall be recorded for each interval. At each interval the test box shall be inspected for lid deformation, failure of the lid or frame welds, vertical and horizontal displacement of the lid frame, cracks, and concrete spalling. After the twentieth loading interval the test shall be terminated with a 60,000 pound load being applied vertically through the steel plate centered on the lid and with the long edge of steel plate orientated parallel to the long axis of the box.

Heavy Duty Junction Boxes will be considered to have withstood the 46,000 pounds test if none of the following conditions are exhibited:

1. Permanent deformation of the lid or any impairment to the function of the lid.
2. Vertical or horizontal displacement of the lid frame.
3. Cracks wider than 0.012-inches that extend 12-inches or more.
4. Fracture or cracks passing through the entire thickness of the concrete.
5. Spalling of the concrete.

Heavy Duty Junction Boxes will be considered to have withstood the 60,000 pounds test if all of the following conditions are exhibited:

1. The lid is operational.
2. The lid is securely fastened.
3. The welds have not failed.
4. Permanent dishing or deformation of the lid is 1/4 inch or less.
5. No buckling or collapse of the box.

#### **9-29.2(2) Standard Duty and Heavy Duty Cable Vaults and Pull Boxes**

Standard Duty and Heavy Duty Cable Vaults and Pull Boxes shall be constructed as a concrete box and as a concrete lid. The lid for the Heavy Duty and Standard Duty Cable Vaults and Pull Boxes shall be interchangeable and both shall fit the same box as shown in the Standard Plans.

The Contractor shall provide shop drawings if their manufacturing process or standard production model includes any deviation from the Standard Plan. For each type of box or whenever there is a design change to the Cable Vault or Pull box, a proof test, as defined in this Specification, shall be performed once in the presence of the Engineer.

**9-29.2(2)A Standard Duty Cable Vaults and Pull Boxes**

Standard Duty Cable Vaults and Pull boxes shall be concrete and have a minimum load rating of 22,500 pounds and be tested in accordance with 9-29.2(1)C for concrete Standard Duty Junction Boxes.

Concrete for standard duty cable vaults and pull boxes shall have a minimum compressive strength of 4000 psi. The frame shall be anchored to the vault/box by welding the wire fabric to the frame or by welding headed studs 3/8 inch x 3 inches long, as specified in Section 9-06.15, to the frame. The wire fabric shall be attached to the studs and frame with standard tie practices. The vault/box shall contain ten studs located near the centerline of the frame and wall. Studs shall be placed one anchor in each corner, one at the middle of each width and two equally spaced on each length of the vault/box. The steel frame, lid support, and lid shall be painted with a black paint containing rust inhibitors or painted with a shop applied, inorganic zinc primer in accordance with Section 6-07.3 or hot dip galvanized in accordance with ASTM A 111.

Material for Standard Duty Cable Vaults and Pull Boxes shall conform to the following:

Concrete	Section 6-02
Reinforcing Steel	Section 9-07
Lid	ASTM A786 diamond plate steel
Frame	ASTM A786 diamond plate steel or ASTM A36 flat steel
Lid Support & Handle	ASTM A36 steel
Anchors (studs)	Section 9-06.15
Bolts, Nuts, Washers	ASTM F593 or A 193, type 304 or 316

**9-29.2(2)B Heavy Duty Cable Vaults and Pull Boxes**

Heavy Duty Cable Vaults and Pull Boxes shall be constructed of concrete having a minimum compressive strength of 4000 psi, and have a minimum vertical load rating of 46,000 pounds without permanent deformation and 60,000 pounds without failure when tested in accordance with Section 9-29.2(1)C for Heavy Duty Junction Boxes.

Material for Heavy Duty Cable Vaults and Pull boxes shall conform to the following:

Concrete	Section 6-02
Reinforcing Steel	Section 9-07
Cover	Section 9-05.15(1)
Ring	Section 9-05.15(1)
Anchors (studs)	Section 9-06.15
Bolts, Nuts, Washers	ASTM F593 or A193, type 304 or 316

**9-29.2(3) Structure Mounted Junction Box**

Surface mounted junction boxes and junction boxes installed in cast in place structures shall be stainless steel NEMA 4X.

Junction boxes installed in structures constructed by slip forming shall be stainless steel NEMA 3R and shall be adjustable for depth, with depth adjustment bolts, which are accessible from the front face of the junction box with the lid installed.

NEMA stainless steel junction boxes and cover screws shall conform to ASTM A 304. Junction boxes installed on exterior of structures shall have an external hinge. Junction boxes shall be labeled with the appropriate designation.

Polyethylene drain tubes for junction boxes mounted in structures shall be 3/8-inch diameter with a wall thickness of 0.062-inches and shall be rated for a 110 psi working pressure at 73°F.

The size of NEMA 4X junction boxes and NEMA 3R junction boxes shall be as shown in the plans.

#### 9-29.2(4) Cover Markings

Junction boxes, cable vaults, and pull boxes with metallic lids shall be marked with the appropriate legend in accordance with the bead weld details in the Standard Plans. Non-metallic lids shall be embossed with the appropriate legend and a non-skid surface. Legends for metallic lids and non-metallic lids shall be 1-inch nominal height.

Junction boxes, cable vaults and pull boxes shall be marked or embossed for use in accordance with the plans and following schedule:

<b>System Type</b>	<b>Legend</b>
Traffic Signal Interconnect (6pr)	COMM
Fiber Optic Trunk Lines	ITS
HUB to TC (25pr)	ITS
Fiber Optic Laterals to CC	ITS
TC to DS (6pr)	ITS
TC to HAR (6pr) SC&DI	ITS
TC to CC (6pr)	ITS
TC to VMS (6pr)	ITS
TC to WSTA (6pr)	ITS
All other lateral 6pr (i.e. neon control, etc)	TS
CC to camera (coax, control cables, old style)	ITS
CC to camera (fiber, new style)	ITS
HAR to antenna (coax)	ITS
VMS to sign (control cables)	ITS
WSTA to temp sensor, weather station	ITS
DS to loops (2cs)	ITS
DS to ramp meter (5c)	ITS
Flashing Beacons	ITS
Neon Power	ITS
Transformers to Cabinets	ITS
Service to Transformers	LT
All power for lighting	LT
Signal Controller to Displays	TS
Signal Controller to Loops	TS
Signal Controller to emergency preempt	TS
Telephone Service Drop	TEL
Telephones at Flyer Stops, Park & Rides, Etc.	TEL

### 9-29.3 Conductors, Cable

For the purpose of this Specification, the neutral conductor is defined as a current carrying conductor with zero potential. For the purpose of this Specification, equipment grounding conductor is defined as the conductor used to connect the noncurrent-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor at the service equipment or at the source of a separately derived system.

Conductors and cable shall conform to the applicable Specifications as follows:

1. All current carrying single conductors shall be stranded copper conforming to ASTM B3 and B8. Insulation shall be 600 volt. Except as allowed in item 3, chemically cross-linked polyethylene or EPR Type USE insulation of code thickness is required for all current carrying single conductors in underground electrical systems. Grounding electrode conductor and bonding jumpers shall be bare or insulated stranded copper, 8 AWG minimum or larger as required by the NEC. Equipment grounding conductors shall be insulated, stranded copper with type XHHW, THWN, or USE insulation, non jacketed 8 AWG minimum or larger as required by the NEC. Insulated Grounding Electrode conductors, bonding jumpers and equipment grounding conductors, shall have continuous green color or green color with one or more yellow stripes.

2. Two and three conductor signal control cable shall consist of three No. 14 stranded copper conductors. Each conductor shall have 20-mil polyethylene insulation and a 10-mil PVC jacket. The cable shall be rated at 600 volts minimum. The cable assembly shall be covered with a polyester tape applied with a 10 percent minimum lap. The overall jacket shall be 45-mil PVC.

Four conductor through 10 conductor signal control cable shall conform to International Municipal Signal Association (IMSA) signal cable Specification 20-1 except the conductor sequence color code as shown in the following table. IMSA Specification cables shall use 14 AWG stranded copper conductors. Individual conductors shall be cabled together in accordance with the following:

Conductor Number	Color Code	Color Trace	Use
1	R	Red	Red or Don't Walk
2	O	Orange	Yellow or Spare
3	G	Green	Green or Walk
4	W	White	Neutral
5	B	Black	Ped Call or Spare
6	Wb	White/Black	Neutral or Spare
7	Bl	Blue	Ped Call or Spare
8	Rb	Red/Black	Red or Don't Walk
9	Ob	Orange/Black	Yellow or Spare
10	Gb	Green/Black	Green or Walk

3. All single conductors employed in traffic control shall be Class B or Class C stranded copper. The minimum wire size shall be 12 AWG. Insulation shall be THW or USE, except loop wire.
4. Triplex or Quadraplex type ACSR neutral self-supporting aerial conductors of the appropriate size for aluminum conductors shall be used where required in the Contract. The neutral conductor shall be the same size as the insulated conductor. All current carrying conductors shall be stranded.
5. Pole and bracket cable shall be a two-conductor cable rated for 600 volts. The individual conductors shall be one red and one black 19-strand No. 10 AWG copper, assembled parallel. The conductor insulation shall be 45-mil polyvinyl chloride or a 600 volt rated cross-linked polyethylene. The Jacketing shall be polyethylene or polyvinyl chloride not less than 45-mils thick. If luminaires with remote ballasts are specified in the Contract, this same cable shall be used between luminaire and ballast for both timber and ornamental pole construction. If the luminaire requires fixture wire temperatures greater than 75°C, the outer jacket shall be stripped for that portion of the cable inside the luminaire. The single conductors shall then be sheathed with braided fiberglass sleeving of the temperature rating recommended by the luminaire manufacturer.
6. Vacant
7. Two conductor shielded (2CS) cable shall have 18 AWG (minimum) conductors and shall conform to IMSA Specification No. 50-2.
8. Detector loop wire may be 12 or 14 AWG stranded copper wire, IMSA 51-3
9. Four conductor shielded cable (4CS) shall consist of a cable with four 18 AWG conductors with polypropylene insulation, an aluminized polyester shield, water blocking material in the cable interstices, and a 26-mil minimum outer jacket of polyethylene. The four-conductor assembly shall be twisted 6 turns per foot. Each conductor shall have a different insulation color. Overall cable diameter shall be 0.25-inch maximum. Capacitance between adjacent pairs shall be 18 pf per foot and 15 pf per foot between diagonal pairs. The capacitances shall not vary more than 10 percent after a 10-day immersion test with ends exposed in a saturated brine solution.
10. Three-conductor shielded cable (3CS) for the detector circuit for optical fire preemption receivers shall consist of three 20 AWG conductors with aluminized mylar shield and one No. 20 drain wire, all enclosed with an outer jacket. All wires shall be 7 X 28 stranded tinned copper material. Conductor insulation shall be rated 75°C, 600 volt. The drain wire shall be uninsulated. Conductor color coding shall be yellow, blue, and orange. DC resistance of any conductor or drain wire shall not exceed 11 ohms per 1,000-feet. Capacitance from one conductor to the other two conductors and shield shall not exceed 48 pf per foot. The jacket shall be rated 80 degree C, 600 volt, with a minimum average wall thickness of 0.045-inch. The finished outside diameter of the cable shall be 0.3-inch maximum.
11. Six pair communications cable (6PCC) shall meet RUS Specification 1755.390 and shall have six pair 22 AWG wires with 0.008-inch FPA/MPR coated aluminum shielding. The cable shall have a petroleum compound completely filling the inside of the cable.

12. Sign light conductors between the hand hole and the isolation switch shall be a two conductor stranded 10 AWG pole and bracket cable, per Section 9-29.3 item 5, and an 8 AWG equipment grounding conductor insulated to 600 volts between conductors. The conductors between the isolation switch and the sign lighting luminaire shall be either code sized individual conductors with cross linked polyethylene type USE insulation or three conductor control cable, stranded copper 14 AWG cable rated at a minimum of 600 volts.

### **9-29.3(1) Fiber Optic Cable**

Each fiber optic cable shall be suitable for placement in an underground duct.

All fibers in the cable shall be usable fibers and shall be sufficiently free of surface imperfections and inclusions to meet or exceed the optical, mechanical, and environmental requirements contained in this Specification.

Cables shall be all dielectric cable (with no armoring) and shall be jacketed (sheathed) with medium density polyethylene. The minimum nominal jacket thickness shall be 71 mils. Jacketing material shall be applied directly over the tensile strength members. The polyethylene shall contain carbon black to provide ultra-violet light protection, and it shall not promote the growth of fungus.

The jacket or sheath shall be free of any holes, splits, or blisters.

The cable shall contain at least one ripcord under the sheath for easy sheath removal.

The shipping, storage, and operating temperature range of the cable shall be -40 degree F to +160 degree F. The installation temperature range of the cable shall be -20 degree F to +160 degree F.

The fiber optic cable shall withstand a maximum pulling tension of 600 pounds (lbs.) during installation (short term) with no damage and 135 pounds (long term).

Each optical fiber shall consist of a doped silica core surrounded by a concentric silica cladding.

Void areas around the individual buffer tubes shall be protected with a moisture resistant compound as a block against moisture migration.

All cables shall be free of material or manufacturing defects and dimensional non-uniformity that would:

1. Interfere with the cable installation using accepted cable installation practices.
2. Degrade the transmission performance and environmental resistance after installation.
3. Inhibit proper connection to interfacing elements.
4. Otherwise yield an inferior product.

The outer jacket material shall be a medium density polyethylene (MDPE) conforming to ASTM D 1248, Type II, Class C, Category 4 or 5, Grade J4. The light absorption coefficient, when measured in accordance with ASTM D 3349, shall be a minimum of 400 at a wavelength of 375 nanometers.

The outer jacket material used in construction of this cable shall be fungus inert as described in ASTM G 21.

Fibers shall contain no factory splices.

The fiber optic cables shall be shipped on wooden reels in lengths as specified in the purchase order with a maximum overage of 10%. The diameter of the drum shall be at least 20 times the diameter of the cable.

**9-29.3(1)A Singlemode Fiber Optic Cable**

Singlemode fibers utilized in the cables specified herein shall be fabricated from 100 kpsi proof stress glass and primarily composed of silica which shall provide a matched clad index of refraction (n) profile and the following physical and performance characteristics:

Maximum Attenuation: 0.4/0.3 dB/km at 1310/1550 nanometers, respectively.

Typical Core Diameter: 8.3 microns

Cladding Diameter: 125 micron

Core-to-Cladding Offset:< 0.8 microns.

(The core center and the cladding center offset is defined as the distance between the core center and the cladding center.)

Cladding Non-Circularity: < 2.0%. Defined as:

{[1-(minimum cladding diameter - maximum cladding diameter)] X 100.}

Coating Diameter of 250 microns  $\pm$  15 microns with a minimum coating thickness at any point of not less than 50 microns.

The coating shall be a dual-layered, UV-cured acrylate applied by the fiber manufacturer.

The coating shall be mechanically or chemically strippable without damaging the fiber.

**9-29.3(2) Twisted-Pair (TWP) Copper Cable**

The TWP cable installed for outside plant (OSP) applications shall contain the amount of twisted, 22 AWG, copper pairs as specified in the Plans. This cable shall be constructed for installation in an underground conduit environment with a sheath consisting of a double coated aluminum shield over which a medium density polyethylene jacket is extruded, in accordance with Rural Utilities Service (RUS) Standard 1755.390. This cable shall be filled with a gel compound to resist water penetration and migration.

The TWP copper cable for OSP applications shall contain no faulty pairs and shall be capable of the transmission of 9600 b/s VF data over distances greater than 7.5 miles.

**9-29.4 Messenger Cable, Fittings**

Messenger cable shall be  $\frac{3}{8}$ -inch, 7-wire strand messenger cables conforming to ASTM A 475, extra-high-strength grade, 15,400 pounds minimum breaking strength, Class A galvanized.

Strain insulators shall be wet process, porcelain, conforming to EEI-NEMA Class 54-2 standards for 12,000 pound ultimate strength.

Down guy assembly shall consist of an eight-way steel expanding anchor, having a minimum area of 300 square inches, made of pressed steel, coated with asphalt or similar preservative, and fitted with a  $\frac{3}{4}$ -inch minimum guy eye anchor rod 8-feet long. As an alternate to expanding anchors, screw type anchors with two 8-inch helix,  $3\frac{1}{2}$ -inch-pitch, 1-inch by 7 foot guy anchor rod, and rated for 7,000 pound maximum torque may be installed.

All pole hardware, bolts, plate rods, hangers, clips, wire guards, and pole bands shall be hot-dipped galvanized in conformance with the requirements of AASHTO M 232.

**9-29.5 Vacant****9-29.6 Light and Signal Standards**

Light standards (including light standards with Type 1 or Type 2 luminaire arms) and signal standards (including Types I, II, III, IV, V, PPB, PS, RM, FB, and CCTV) shall be in accordance with the details shown in the Plans, as specified in the Special Provisions and as outlined herein, provided that only one luminaire arm type shall be used throughout the project.

Fabrication of light and signal standards shall conform to the applicable requirements of Section 6-03.3(14).

Light standard, signal standards, slip base hardware and foundation hardware shall be hot-dipped galvanized in accordance with AASHTO M 111 and AASHTO M 232.

**9-29.6(1) Steel Light and Signal Standards**

Steel plates and shapes for light and signal standards shall conform to ASTM A 36, except that structural shapes may conform to ASTM A 992. Shafts for light and signal standards, except Type PPB signal standards, shall conform to ASTM A 572 Grade 50. Shafts and caps for Type PPB signal standards, slipfitters for type PS I, FB, and RM signal standards, and all pipes shall conform to ASTM A 53 Grade B. Base plates for light standards shall conform to ASTM A 572, Grade 50, except as otherwise noted in the Standard Plans for fixed base light standards. Base plates for signal standards shall conform to ASTM A 36. Connecting bolts shall conform to AASHTO M 164. Fasteners for handhole covers, bands on lighting brackets, and connector attachment brackets shall conform to ASTM F 593.

Light and signal standards shall be hot-dipped galvanized in accordance with AASHTO M 111 and AASHTO M 232.

Steel used for light and signal standards shall have a controlled silicon content of either 0.00 to 0.04 percent or 0.15 to 0.25 percent. Mill test certificates verifying the silicon content of the steel shall be submitted to both the galvanizer and the Engineer prior to beginning galvanizing operations.

**9-29.6(1)A Vacant****9-29.6(2) Slip Base Hardware**

Slip plates and anchor plates for light standards and for Type FB and RM signal standards shall conform to the requirements of ASTM A 572 Grade 50. The keeper plate shall be 28 gage, conforming to ASTM A 653 coating designation G 90. Clamping bolts for slip base assemblies and slip base adapters shall conform to AASHTO M 164. Studs and bolts for slip base adapters shall conform to AASHTO M 164. Nuts shall conform to AASHTO M 291 Grade DH. Hardened washers shall conform to AASHTO M 293. Plate washers shall conform to ASTM A 36, and also shall conform to the flatness tolerances specified in AASHTO M 293 for circular washers.

Galvanized bolts shall meet Standard Specification 9-06.5(4).

**9-29.6(3) Timber Light Standards, Timber Strain Poles, Timber Service Supports**

All timber poles used in illumination or traffic signal systems shall be Douglas fir, machine shaved, roof sawed, conforming to the latest ANSI Specifications and Dimensions for Wood Poles.

All timber poles shall be gained according to industry standards. A dated nail or metallic date plate shall be set in the gain evidencing the year of treatment of the timber pole.

All poles shall be treated with pentachlorophenol in accordance with Section 9-09.3(1).

Tops shall be sawed before treatment. Where holes are bored in poles to accommodate hanging bolts for brackets, transformers, guy assemblies, or other accessories, such holes shall be painted with a solution of the above preservative.

#### **9-29.6(4) Welding**

Welding of steel structures shall be in accordance with AWS D1.1/D1.1M, latest edition, Structural Welding Code, and Section 6-03.3(25).

#### **9-29.6(5) Foundation Hardware**

Anchor bolts for Type PPB, PS, I, FB, and RM signal standards shall conform to the requirements of ASTM A 307. Nuts shall meet the requirements of AASHTO M 291. Washers shall meet the requirements of ASTM F 844.

Anchor bolts, and associated nuts and washers, for Type CCTV, II, III, IV, and V signal standards and luminaire poles shall conform to Section 9-06.5(4). Anchor rods conforming to ASTM A 449 may be substituted, provided that the galvanized ASTM A 449 anchor rods having an ultimate tensile strength above 145 ksi shall be tested for embrittlement in accordance with either ASTM A 143 (if the rod length is equal to or greater than five times the bolt diameter) or ASTM F 606 Section 7 (if the rod length is less than five times the nominal bolt diameter).

All foundation hardware shall be 100% hot-dipped galvanized in accordance with AASHTO M 111 and AASHTO M 232.

#### **9-29.7 Luminaire Fusing and Electrical Connections at Light Standard Bases, Cantilever Bases and Sign Bridge Bases**

Unfused quick-disconnect connectors shall conform to the following requirements:

1. A copper pin and a copper receptacle both of at least 90 percent conductivity shall be crimped or a stainless steel allen head screw and lug connection to the cable. If the allen head screw is used, the allen head screw shall be torqued to the manufactures recommendations. All crimped connections shall use a copper connector installed with a positive action (ratchet) tool. The receptacle shall establish contact pressure with the pin through the use of a copper beryllium sleeve spring and shall be equipped with a disposable mounting pin. The pin shall be of at least half-hard material and the crimping portion shall be fully annealed while the rest of the pin is maintained in its original state of hardness. The receptacle shall be fully annealed. Both the copper pin and receptacle shall have a centrally located recessed locking area adapted to be complementarily filled and retained by the rubber housing.
2. A plug and a receptacle housing shall be made of water resistant synthetic rubber which is capable of burial in the ground or installation in sunlight. Each housing shall provide a section to form a water-seal around the cable, have an interior arrangement to suitably and complementarily receive and retain the copper pin or receptacle, and a section to provide a water-seal between the two housings at the point of disconnection.

Fused quick-disconnect kits shall provide waterproof in-line fuse protection. The kit shall provide three cutoff sections on both lines and load side to accommodate various wire sizes. All connections shall be as described in item "1" above. Upon disconnect, the fuse shall remain in the load side of the kit.

Fuses furnished for all lighting circuits shall be capable of handling the operating voltage of the circuit involved and shall have the following characteristics:

1. Fuses shall be capable of indefinitely supporting 110 percent of the rated load.
2. Fuses shall be capable of supporting 135 percent of the rated load for approximately 1 hour.
3. A load of 200 percent of rated load shall effectively cause instantaneous blowing of the fuse.
4. Fuses shall be rated as listed below and shall be sized to fit the fuse containers furnished on this project, according to the manufacturer's recommendations therefore.
5. Fuses shall be UL Listed.

Luminaire Size	Service Voltage		
	480V	240V	120V
1,000W	10A	15A	30A
750W	5A	10A	20A
700W	5A	10A	20A
400W	5A	10A	15A
310W	5A	5A	10A
250W	5A	5A	10A
200W	4A	5A	10A
175W	4A	5A	10A
150W	3A	4A	5A
100W	2A	3A	4A
70W	2A	2A	2A
50W	2A	2A	2A

#### 9-29.8 Vacant

#### 9-29.9 Ballast, Transformers

Each ballast shall have a name plate attached permanently to the case listing all electrical data.

Certificates of compliance, to manufactures Specifications and these Specifications, shall be submitted by the manufacturer with each type of luminaire ballast.

Ballasts shall be designed for continuous operation at ambient air temperatures from 20 degree F without reduction in ballast life. Ballasts shall have a design life of not less than 100,000 hours. Ballasts shall be designed to operate for at least 180 cycles of 12 hours on and 12 hours off, with the lamp circuit in an open or short-circuited condition and without measurable reduction in the operating requirements. All ballasts shall be high power factor (90%).

Ballasts shall be tested in accordance with the requirements of current ANSI C 82.6, Methods of Measurement of High-Intensity-Discharge Lamp Ballasts. Starting aids for ballasts of a given lamp wattage shall be interchangeable between ballasts of the same wattage and manufacturer without adjustment.

Ballast assemblies shall consist of separate components, each of which shall be capable of being easily replaced. A starting aid will be considered as a single component. Each component shall be provided with screw terminals, NEMA tab connectors or a single multi-circuit connector. All conductor terminals shall be identified as to the component terminal to which they connect.

Heat-generating components shall be mounted to use the portion of the luminaire upon which they are mounted as a heat sink. Capacitors shall be located as far as practicable from heat-generating components or shall be thermally shielded to limit the fixture temperature to 160 degree F.

Ballasts for high-pressure sodium lamps shall have a ballast characteristic curve which will intersect both of the lamp-voltage limit lines between the wattage limit lines and remain between the wattage limit lines throughout the full range of lamp voltage. This requirement shall be met not only at the rated input voltage of the ballast, but also the lowest and highest input voltage for which the ballast is rated. Throughout the lifetime of the lamp, the ballast curve shall fall within the specified limits of lamp voltage and wattage.

All luminaires ballasts shall be located within the luminaire housing. The only exception shall be ballasts to be mounted on lowering assemblies and shall be external to, and attached to the fixture assembly.

No capacitor, transformer, or other device shall employ the class of compounds identified as polychlorinated biphenyls (PCB) as dielectric, coolants, or for any other purpose.

Ballast Characteristics for High Pressure Sodium (HPS) and Metal Halide (MH) Sources shall be:

Source	Line Volt.	Lamp Wattage	Ballast Type	Input Voltage Variation	Lamp Wattage Variation
HPS	any	70 400	Mag. Reg. Lag	10%	18%
HPS	any	750 1000	Auto Reg. Lead CWA	10%	30%
MH	any	175 400	Mag. Reg. Lag	10%	18%
MH	any	1000	Auto Reg. Lead CWA	10%	30%

Transformers and inductors shall be resin-impregnated for protection against moisture. Capacitors, except those in starting aids, shall be metal cased and hermetically sealed.

The transformers to be furnished shall be indoor/outdoor dry type transformers rated as shown in the Plans. The transformer coils, buss bar, and all connections shall be copper. Transformers, 7.5 KVA and larger shall be supplied with two full capacity taps, one at 5% and one at 10% below the normal full capacity.

**9-29.10 Luminaires**

If not listed on the Qualified Products List (QPL) a Certificate of Compliance shall be submitted by the manufacturer with each type of luminaire. The certificate shall state that the lot of luminaires meets this Specification:

- A. All luminaires shall be of the IES distribution type and wattage indicated in the Contract. Luminaires shall be installed with HPS lamps rated at 24,000 hours, unless otherwise specified in the Contract or this Specification.
- B. Conventional highway luminaires shall provide a full cut-off distribution and a high pressure sodium light source.
- C. Horizontal luminaires shall attach to 2-inch pipe tenons on mast arms. Vertical mounted luminaires shall be appropriately sized for their respective pole top tenons.
- D. All luminaires shall have their component secured to the luminaire frame with AISI, 300 series chrome-nickel grade stainless steel, zinc dichromate coated steel or ceramic coated steel hardware for corrosion resistant and chemical bonding resistant attachment to the cast aluminum housing or doors. The luminaire slip-fitter bolts shall be either stainless steel, hot-dip galvanized steel, zinc dichromate coated steel, or ceramic coated steel. All internal luminaire assemblies shall be assembled on or fabricated from either stainless steel or galvanized steel. The housing, complete with integral ballast, shall be weathertight. The ballast and lamp housing shall be on the same level.
- E. All luminaires shall be mounted level, both transverse and longitudinally, as measured across points specified by the manufacturer. Leveling and orientation shall be accomplished after pole plumbing. Highway and decorative luminaires shall have slip-fitters capable of adjusting through a 5-degree axis for the required leveling procedure.
- F. Refractors shall be formed from heat resistant, high impact, molded borosilicate glass. Flat lens shall be formed from heat resistant, high impact borosilicate or tempered glass.
- H. High pressure sodium cobra head luminaires shall be capable of accepting a 150, 200, 250, 310, or 400 watt lamp complete with ballast. Metal halide fixtures shall be capable of accepting a 175, 250 or 400 watt lamp complete with ballast. Mercury vapor fixtures shall be capable of accepting a 175, 250, 400 watt lamp complete with ballast. Metal halide fixture shall accept a 175 watt mercury vapor lamp complete with ballast. Each luminaire shall consist of a housing, a reflector, lens, a lamp socket, an integral ballast, a terminal strip and lamp.
- G. Housings shall be fabricated from aluminum. Painted housings shall be painted flat gray, Federal Standard 595B color chip No. 26280. Housings that are painted shall withstand a 1,000-hour salt spray test as specified in ASTM B 117.

All luminaires to be mounted on horizontal mast arms, shall be capable of withstanding cyclic loading in:

1. A vertical plane at a minimum peak acceleration level of 3.0 g's peak-to-peak sinusoidal loading (same as 1.5 g's peak) with the internal ballast removed, for a minimum of 2 million cycles without failure of any luminaire parts, and

2. A horizontal plane perpendicular to the direction of the mast arm at a minimum peak acceleration level of 1.5 g's peak to peak sinusoidal loading (same as 0.75 g's peak) with the internal ballast installed, for a minimum of 2 million cycles without failure of any luminaire parts.

The temperature rating of all wiring internal to the luminaire housing, excluding the pole and bracket cable, shall equal or exceed 200 degree F.

All luminaires shall be provided with markers for positive identification of light source type and wattage. Markers shall be 3-inches square with Gothic bold, black 2-inch legend on colored background. Background color shall be gold for sodium, blue for mercury, and red for metal halide light sources. Legends shall be sealed with transparent film resistant to dust, weather, and ultraviolet exposure.

Legends shall correspond to the following code:

Lamp	Wattage Legend
70	7
100	10
150	15
175	17
200	20
250	25
310	31
400	40
700	70
750	75
1,000	XI

#### 9-29.10(1) Cobra Head Luminaires

Conventional highway luminaires shall be IES Type III cut off type distribution cobra head configuration with horizontal lamp. The ballast shall be mounted on a separate exterior door, which shall be hinged to the luminaire and secured, in the closed position to the luminaire housing by means of an automatic type of latch (a combination hex/slot stainless steel screw fastener may supplement the automatic type latch). The reflector of all luminaires shall be of a snap-in design or be secured with screws. The reflector shall be manufactured of polished aluminum or molded from prismatic formed borosilicate glass. The refractor or lens shall be mounted in a doorframe assembly which shall be hinged to the luminaire and secured in the closed position to the luminaire by means of automatic latch. The refractor or lens and doorframe assembly, when closed, shall exert pressure against a gasket seat. The refractor lens shall not allow any light output above 90 degrees nadir. Gaskets shall be composed of material capable of withstanding temperatures involved and shall be securely held in place.

Each housing shall be provided with a slipfitter capable of mounting on a 2-inch pipe tenon. Vertical mounted luminaires shall be appropriately sized for their respective pole top tenon and capable of being adjusted within 5 degrees from the axis of the tenon. The clamping bracket(s) and the cap screws of the slipfitter shall not bottom out on the housing bosses when adjusted within the  $\pm 5$  degree range.

No part of the slipfitter mounting brackets on the luminaires shall develop a permanent set in excess of 0.2-inch when the cap screws used for mounting are tightened to a torque of 32 pounds feet.

#### **9-29.10(2) Decorative Luminaires**

Decorative fixture shall provide for a 150 - 400 watt HPS lamp fully enclosed fixture with mogul lamp socket, adjustable where required to alternate cutoff distributions.

The fixture shall be a one piece, box shaped, raintight, dusttight and corrosion resistant, integral unit. The unit shall consist of an accessible ballast compartment and a sealed housing which permits filtered pressure equalization.

The ballast housing shall be fabricated of close tolerance extruded aluminum with heat resistant vinyl finish. The housing shall be adequately constructed to contain ballasts for 150 - 400 watt alternate high intensity discharge sources.

Each housing shall consist of an integral Alzak reflector, containing a mogul based high intensity discharge lamp, a rigid box type lamp holder assembly, a reflector assembly with a lamp vibration damper, and a one piece heat and shock resistant, clear tempered lens mounted in a gasketed, hinged, and baffled extruded aluminum frame. The housing shall have vinyl heat resistant finish. One fourth inch stainless steel, series 300 fasteners shall secure the lens frame to the housing.

The auxiliary equipment compartment for ballast terminals shall be separated from the lamp compartment by a metal heat barrier. The chassis shall be designed to provide effective heat sinking from the ballast cores. Capacitors shall be mounted at least 5-inches from the core and coil components.

Fixtures shall be finished alternately with paint or epoxy primer and either acrylic enamel; vinyl clad aluminum or powdered polyester baked on paint. Aluminum compatible epoxy primer shall be applied. The finish coat shall be dark bronze in color matching Federal Standard 595B or as shown in the Contract.

Without chipping or flaking, the finish shall withstand 5 foot pounds direct or indirect impact from a falling cylindrical steel rod  $\frac{7}{8}$ -inch diameter, a hemispheric nose and shall be salt spray resistant after 300 hours exposure in accordance with ASTM B 117 shall not cause blistering, peeling, corrosion or loss of adhesion.

Decorative fixtures shall be mounted using a reinforced mounting arm, milled to provide a smooth fit between fixture and arm. A slipfitter assembly shall be provided for leveling purposes, between fixture and tenon. Two  $\frac{7}{16}$ -inch or larger stainless steel bolts, series 300, shall be used to mount the fixture to the tenon. An approved gasket shall be utilized to seal against weather. A smooth wireway shall be provided.

All decorative fixtures shall be of the same manufacturer and external appearance.

#### **9-29.10(3) High Mast Luminaires and Post Top Luminaires**

High mast and post top luminaires shall comply with the requirements of the Contract and Section 9-29.9 except the unit lamp shall utilize a vertically positioned lamp. High mast luminaires shall be 400 watt HPS full 90 degree nadir cut off, capable of types 2, 3, 5 distribution or as shown in the Contract. When installed at heights between 50 and 70-feet the bottom of the fixture shall be closed, at heights from 70 to 85-feet the bottom shall be open. High Mast luminaires poles with mounting heights greater than 50-feet shall have approved fixture lowering device installed and a remote control unit, to operate the lowering device. The remote control unit shall be capable of operating the lowering device while permitting the operator to stand clear of the lights being lowered.

Post top luminaires shall have the ballast located directly below the vertical installed HPS lamp. All post top luminaires shall be capable of accepting 70, 100, 200, 250, 400 watt HPS lamps complete with ballast assembly.

Housings shall be fabricated from aluminum. All housings shall be painted flat gray, Federal Standard 595B color chip No. 26280. All housings shall withstand a 1,000-hour salt spray test as specified in ASTM B 117.

#### **9-29.10(4) Underdeck and Wall Mount Luminaires**

Underdeck luminaires shall be weatherproof and corrosion resistant. Light distribution shall be as shown on the Contract. Each flush-mounted underdeck luminaire shall consist of a metal body, a prismatic refractor mounted in a doorframe, a prismatic glass or specular anodized aluminum reflector, a ballast, and a ceramic lamp socket and be supplied complete with all fasteners. The body shall have provisions for anchoring to concrete. The refractor shall be glass and shall be clearly identified as to "street side." The doorframe assembly shall be hinged, gasketed and secured to the body.

Each wall-mounted luminaire shall consist of a metal body, a prismatic refractor mounted in a doorframe, an aluminum reflector with a specular anodized finish, an integral ballast and a ceramic lamp socket and supplied with all fasteners. The refractor shall be glass. A gasket shall be provided between the refractor and the body of the fixture.

All lamp sockets shall be positioned to locate the light center of the lamp within ½-inch of the light center location for which the luminaire is designed.

Ballasts for underdeck and wall luminaires shall conform to the provisions in Section 9-29.9. Ballasts for underdeck and wall mount luminaires shall be installed in the luminaire housing.

#### **9-29.10(5) Sign Lighting Luminaires**

Sign lighting luminaires shall be either Mercury Vapor or Induction.

##### **9-29.10(5)A Sign Lighting Luminaires – Mercury Vapor**

Sign lighting luminaires shall have a cast aluminum housing and door assembly with a polyester paint finish.

The housing shall encase a reflector, lamp socket, and ballast. It shall have a front entry (the side facing the sign) suitable for ½-inch conduit and mounting holes for attaching to a fixture mounting plate. Any additional entries shall have suitable plugs. The sign lighting luminaire shall be supported by a lighting bracket assembly as detailed in the plans. If the sign structure includes a maintenance walkway, the luminaire fixture mounting plate shall be bolted to the walkway grating. Condensation drain holes shall be provided as recommended by the manufacturer.

The door shall be hinged to the housing on the side of the fixture away from the sign panel and shall be provided with two captive devices. The door shall be provided with the means to allow the door to be locked in the open position 70 degree to 90 degree from the plane of the door opening. The juncture of the door and housing shall be gasketed to provide a rain tight and dust tight joint.

Refractors shall be manufactured from heat resistant borosilicate glass. The refractor shall be shielded so that no light source is visible from the sign viewing approach. The shield shall be an integral part of the door assembly. When called for in the plans, fixtures shall be provided with a wire guard to prevent damage to the refractor.

The light source shall be a 175 watt deluxe phosphor coated mercury vapor lamp. The lamp socket shall be porcelain enclosed mogul type containing integral lamp grips to ensure electrical contact under conditions of normal vibration. The center contact shall be spring loaded. The shell and center contact shall be rated for 1500 watts, 600 volts.

An isolation switch shall be installed in a NEMA 3R stainless steel terminal cabinet per Standard Specification Section 9-29.25. The terminal cabinet shall be installed in accordance to the Standard Plans. The switch shall be either single pole, single throw, or double pole single throw as necessary to open all conductors to the luminaires other than neutral and ground conductors. The switch shall contain 600 volt alternating current (VAC) terminal strips on the load side with solderless lugs as required for each load carrying conductor plus four spare lugs per strip.

Each fixture shall be provided with a fusible terminal block. Fuses shall be 10 amp, 250 VAC for 120 VAC circuits and 5 amp 600 VAC for 240 VAC and 480 VAC circuits. The primary voltage shall be as indicated in the plans. Photometric performance shall be as follows:

- A. The ratio of the maximum to minimum illuminance level on a panel 10-feet high by 16-feet wide shall not numerically exceed 5:1 approaching 1:1. In addition, the illuminance gradient shall not numerically exceed 2:1, illuminance gradient being defined as the ratio of the minimum illuminance of a square panel 1-foot on a side to that of any adjacent panel of the same size. This performance shall be obtained when the fixture is mounted 1-foot below the bottom edge of the sign and 5-feet out from the sign face.
- B. The average to minimum uniformity ratio for a panel as dimensioned above shall not numerically exceed 3:1. Average initial illuminance shall exceed 10 foot candles for a mercury vapor lamp of 175 watts as specified.

#### **9-29.10(5)B Sign Lighting Fixtures-Induction**

Induction sign lighting fixture shall conform to the provisions for mercury sign lighting fixtures except as modified by this section.

Each fixture shall consist of a housing, a reflector, refractor or lens, lamp socket, lamp, power coupler, a high frequency (HF) generator and a fuse block, door, front entry (the side facing the sign) suitable for ½-inch conduit and mounting holes for attaching to a fixture mounting plate. Any additional entries shall have suitable plugs. The sign lighting luminaire shall be supported by a lighting bracket assembly as detailed in the plans. The door shall be hinged to the housing on the side of the fixture away from the sign panel and shall be provided with two captive devices. The door shall be provided with the means to allow the door to be locked in the open position 70 degree to 90 degree from the plane of the door opening. The juncture of the door and housing shall be gasketed to provide a rain tight and dust tight joint.

Refractors or lens shall be manufactured from heat resistant glass. The refractor or lens shall be shielded so that no light source is visible from the sign viewing approach. The shield shall be an integral part of the door assembly. When called for in the plans, fixtures shall be provided with a wire guard to prevent damage to the refractor.

The ratio of the maximum to minimum illuminance level on a panel 10-feet high by 16-feet wide shall not numerically exceed 9:1 approaching 1:1. In addition, the illuminance gradient shall not numerically exceed 2:1, illuminance gradient being defined as the ratio of the minimum illuminance of a square panel 1-foot on a side to that of any adjacent panel of the same size. This performance shall be obtained when the fixture is mounted 1-foot below the bottom edge of the sign and 5-feet out from the sign face.

The average to minimum uniformity ratio for a panel as dimensioned above shall not numerically exceed 4:1. Average initial illuminance shall exceed 10 foot candles for an induction lamp of 85 watts as specified.

The system lifetime shall be rated at 60 000 hours with a failure rate of less than 10 percent. The system shall be rated at a nominal wattage of 87 W, 120/240 or 480V(ac). The power factor of the system shall be greater than 90 percent and the total harmonic distortion (THD) shall be less than 10 percent. The system shall be UL approved for wet locations and be FCC Class a listed.

The mounting assembly shall be either cast aluminum, hot-dip galvanized steel plate or steel plate that has been galvanized and finished with a polymeric coating system or the same finish that is used for the housing. The overall weight of the fixture shall not exceed 44 pounds. The manufacturer's brand name, trademark, model number, serial number and date of manufacture shall be located on the packaged assembly and on the outside and inside of the housing.

#### **Housing**

The housing shall have a door designed to hold a refractor or lens. The housing door shall be designed to be opened without the use of tools. The housing and door shall have polyester paint finish of a gray color resembling unfinished fabricated aluminum.

#### **Reflector**

The reflector may be designed to be removed as a unit that includes the lamp and power coupler.

#### **Lamp**

Each fixture shall be furnished with an 85-W induction lamp. The interior lamp walls shall be fluorescent phosphor coated. Lamp light output shall be not less than 70 percent at 60,000 hours. Lamps shall have a color-rendering index (CRI) of not less than 80. Lamps shall be rated at a color temperature of 4,000 K. Lamps shall be removable without the use of tools.

#### **Power Coupler**

The power coupler shall consist of a construction base with antenna, heat sink and electrical connection cable. The power coupler shall be designed so that it can be removed with no more than common hand tools.

#### **High Frequency Generator**

High frequency (HF) generators shall provide reliable lamp starting and operation at ambient temperatures down to -15°F for the rated life of the lamp.

The generator output frequency shall be 2.65 MHz +/- 10 percent. The generator radio frequency interference shall meet the requirements of Part 18 of the FCC.

High frequency generators shall be designed for continuous operation at ambient air temperatures from -5°F to 80°F without reduction in generator life. High frequency generators shall have a design life of not less than 100,000 hours at 130° F.

A Certificate of Compliance, conforming to the provisions in Section 1-06.3. "Certificates of Compliance," and a copy of the high frequency generator test methods and results shall be submitted by the manufacturer with each lot of sign lighting fixtures. The certificate shall state that the high frequency generators meet, in every respect, the above requirements and the generator Specifications of the lamp manufacturer. High frequency generators shall also conform to the following:

- A. High frequency generators shall be capable of being easily replaced. All conductor terminals shall be identified as to the component terminal to which they connect.
- B. High frequency generators shall be mounted so as to use the portion of the sign lighting fixture upon which they are mounted as a heat sink.

#### **9-29.11 Control Equipment**

Illumination circuits shall be controlled by a combination of photoelectric controls and lighting contactors or mercury relays as noted in the Contract.

##### **9-29.11(1) Time Clock Controls**

Time clocks, when specified in the Contract, shall be solid state and shall have a battery backup. The clock shall provide four functions and shall be enclosed within a dust tight mounting case. The unit shall be mounted on vibration dampened fittings.

The unit shall be push button programmable with 15 events per week, selectable by day of week and time of day to the nearest minute.

The clock shall be accurate to plus or minus 15 seconds per month through a humidity variation of 0 to 95 percent and a temperature variation of 0°F to 150°F. The clock shall be within plus or minus 10 seconds after 10 hours of battery backup operation. The backup battery shall operate for 24 hours minimum.

Contacts shall be rated at 5 amps tungsten load for up to 100,000 cycles. Each clock function shall operate a 120 VAC normally open and normally closed set of contacts.

##### **9-29.11(2) Photoelectric Controls**

The photoelectric control shall be the twistlock type and the light sensitive element shall be a solid state photo diode. The control shall be designed to turn on at 3 foot-candles (32 lux) and turn off at 1.8 foot-candles (20 lux). The lighting control shall not drift by more than 1 percent over a 10-year period.

The output control relay shall have a 45-second time delay to prevent false turn-off caused by momentary brightness. This output relay shall be rated 1,000 watts incandescent or 15 amps inductive load. The contacts shall be normally closed. The unit shall be designed to not continuously pulse the output relay if the photo control bypass switch is energized.

The lighting control shall have a built in metal oxide varistor (MOV) rated 180 joules for lightning and transient protection. The control shall also have secondary zener diode and transient filter. The printed circuit board shall be coated to prevent corrosion. The normal operating voltage range will be 105 to 285 VAC.

#### **9-29.12 Electrical Splice Materials**

Splicing in illumination circuits will be permitted only at junction boxes. With the exception of lead-in cable to loop wire or magnetometer sensing probe splices, no splices will be allowed in traffic signal circuitry. All other traffic signal circuitry will be terminated at a load, at control equipment, or at a terminal.

##### **9-29.12(1) Illumination Circuit Splices**

Aerial splices may employ split bolt connectors. Splices and taps on underground circuits shall be made with solderless crimp connectors to securely join the wires both mechanically and electrically. Aerial splices may employ split bolt connectors. Two way inline splices meeting Mil Spec I 230053 at or below grade locations shall employ

moisture blocking heat shrink, Mil Spec I-23053 or be epoxy resin cast type insulation employing clear rigid plastic molds. Clear mylar sheet bonded to butyrate webbing forming a flexible mold shall be used for four-way or more splices. The material used shall be compatible with the insulation material utilized. Equipment and methods shall be as recommended by the manufacturer of the splicing materials. The component materials of the resin insulation shall be packaged form ready for convenient mixing without removing from the package. Only one conductor or one multi conductor cable per wire entrance will be allowed in any rigid mold splice.

#### **9-29.12(2) Traffic Signal Splice Material**

Induction loop splices and magnetometer splices shall be either moisture blocking two-way (in line) heat shrink, meeting Mil Spec I-23053, or epoxy resin cast type with clear rigid plastic molds or re-enterable type with semi-hardening epoxy filling compound that remains semi-flexible enclosed in a re-enterable rigid mold with end cap seals.

#### **9-29.13 Traffic Signal Controllers**

A controller shall consist of a complete electrical mechanism for controlling the operations of traffic control signals including the timing mechanism and all necessary auxiliary equipment, mounted in a cabinet.

The Contractor shall furnish to the Contracting Agency all guarantees and warranties furnished as a normal trade practice for all control equipment that is provided.

The fabricator of the controller shall perform quality control (QC) inspections based on their QC program. Their QC program shall be submitted and approved by WSDOT at least annually. The fabricator of the controller shall certify that the controller meets all requirements of the Standard Specifications and Special Provisions for the specific application.

The QC program shall include, but not be limited to, the following:

1. Quality Statement
2. Individual responsible for quality (organizational chart)
3. Fabrication procedures
4. Test procedures
5. Documented inspection reports
6. Documented test reports
7. Certification package

Control equipment includes all equipment used to control the operations of traffic control signals, programmable message signs, illumination system's and other associated control systems. Control equipment includes all devices including auxiliary equipment mounted in a cabinet.

The traffic signal control equipment shall conform to the Contract Specifications and these Standard Specifications.

All control equipment shall be as specified below:

- A. NEMA control and all auxiliary equipment shall conform to current NEMA Specifications.
- B. Type 170E control equipment and all auxiliary equipment, shall conform to the California Department of Transportation document entitled "Transportation Electrical Equipment Specifications" dated November 19, 1999.

- C. The 170E/HC-11 controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 170E/HC-11 controller and auxiliary equipment. The 170E shall be compatible with Type 170E controllers and the current revision of the software specified in the Contract.
- D. 170 ATC controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 170 ATC controller and auxiliary equipment.
- E. Type 2070 controller and all auxiliary equipment shall conform to the current California Department of Transportation Specification for Model 2070 and auxiliary equipment.
- F. Type 2070 Lite controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 2070 Lite controller and auxiliary equipment.

All traffic signal control equipment shall be tested as follows. The supplier shall:

1. Seven days prior to shipping, arrange appointment for controller cabinet assembly, and testing at the WSDOT Materials Laboratory or the facility designated in the Special Provisions.
2. Assembly shall be defined as but not limited to tightening all screws, nuts and bolts, verifying that all wiring is clear of moving parts and properly secured, installing all pluggables, connecting all cables, Verify that all Contract required documents are present, proper documentation is provided, and all equipment required by the Contract is installed.
3. The assembly shall be done at the designated WSDOT facility in the presence of WSDOT personnel.
4. The supplier shall demonstrate that all of the functions required by this Specification and the Contract Plans and Special Provisions perform as intended. Demonstration shall include but not be limited to energizing the cabinet and verifying that all 8 phases, 4 pedestrian movements, 4 overlaps (as required by the Contract Provisions) operate per Washington State Standard Specifications Section 9-29.13. The supplier shall place the controller in minimum recall with interval timing set at convenient value for testing purposes. Upon a satisfactory demonstration the controller assembly will then be accepted by WSDOT for testing.
5. If the assembly, and acceptance for testing is not complete within 5 working days of delivery, the Project Engineer may authorize the return of the assembly to the supplier, with collect freight charges to the supplier.
6. The Contractor will be notified when the testing is complete, and where the assembly is to be picked-up for delivery to the project.
7. The supplier has 5 working days to repair or replace any components that fail during the testing process at no cost to the Contracting Agency. A failure shall be defined as a component that no longer functions as intended under the conditions required or does not meet the requirements of the Contract Specifications and is at the sole discretion of WSDOT.
8. Any part or component of the controller assembly, including the cabinet that is rejected shall not be submitted for use by WSDOT or any City or County in the State of Washington.

**9-29.13(1) Vacant****9-29.13(2) Flashing Operations**

All traffic signals shall be equipped for flashing operation of signal displays. Controllers shall be programmed for flashing red displays for all approaches. During flash display, all pedestrian circuits shall be de-energized.

Actuated traffic signal control mechanisms shall be capable of entry into flash operation and return to normal operation as follows:

1. Terminal Strip Input (Remote Flash). When called as a function of a terminal strip input, the controller shall provide both sequenced entry into flash and sequenced return to normal operation consistent with the requirements of the latest edition of the Manual on Uniform Traffic Control Devices.
2. Police Panel Switch. When the flash-automatic switch located behind the police panel door is turned to the flash position, the signals shall immediately revert to flash; however, the controller shall “STOP TIME.” When the switch is placed on automatic, the signals shall immediately time an 8-10 second all red period then resume normal cyclic operations at the beginning of major street green.
3. Controller Cabinet Switches. When the flash-automatic switch located inside the controller cabinet is placed in the flash position, the signals shall immediately revert to flash; however, the controller shall continue to function. When the flash-automatic switch is placed in the automatic position, the controller shall immediately resume normal cyclic operation at the beginning of the artery green. Adjacent to the flash-automatic switch shall be a controller on-off switch. If the flash-automatic switch is in the automatic position and the controller on-off switch is placed in the OFF position, the signals shall immediately revert to flash.
4. Power Interruption. On “NEMA” controllers any power interruption longer than 475 plus or minus 25 milliseconds, signals shall re-energize consistent with No. 2 above to ensure an 8-second flash period prior to the start of major street green. A power interruption of less than 475 plus or minus 25 milliseconds shall not cause resequencing of the controller and the signal displays shall re-energize without change. Type 170 controllers shall re-energize consistent with No. 2 above after a power interruption of 1.75 plus or minus 0.25 seconds. The 8-second flash period will not be required.
5. Conflict Monitor. Upon sensing conflicting signals or unsatisfactory operation voltages, the conflict monitor shall immediately cause the signal to revert to flash; however, the controller shall stop time at the point of conflict. After the conflict monitor has been reset, the controller shall immediately take command of the signal displays at the beginning of major street green.

**9-29.13(3) Emergency Preemption**

Immediately after a valid call has been received, the preemption controls shall cause the signals to display the required clearance intervals and subsequent preemption intervals. Preemption shall sequence as noted in the Contract. Preemption equipment shall be installed so that internal wiring of the controller, as normally furnished by the manufacturer, is not altered. Termination of the preemption sequence shall place a call on all vehicle and pedestrian phases. Preemption indicators, if required, shall turn on when the controller reaches the preempted phase. NEMA controller shall energize the pre-

emption indicators when the controller is in the pre-emption phase(s). For the type 170, 2070, ATC, 2070 Lite controllers, the pre-emption indicators shall be energized when the pre empt detector registers the pre empt request call.

#### **9-29.13(4) Wiring Diagrams**

Schematic wiring diagrams of the controllers and auxiliary equipment shall be submitted when the controllers are delivered. The diagram shall show in detail all circuits and parts. The parts shall be identified by name or number in a manner readily interpreted. One reproducible mylar or two microfilms and four copies of the cabinet wiring diagram and component wiring diagrams shall be furnished with each cabinet and if requested by the Engineer on a high density disk or CD. The schematic drawing shall consist of a single sheet, detailing all circuits and parts, not to exceed 52-inches by 72-inches. The cabinet wiring diagram shall indicate and identify all wire terminations, all plug connectors, and the locations of all equipment in the cabinet. Included in the diagram shall be an intersection sketch identifying all heads, detectors, and push buttons and a phase diagram.

#### **9-29.13(5) Vacant**

#### **9-29.13(6) Radio Interference Suppressers**

All traffic signal controllers, flashers, or other current-interrupting devices shall be equipped with radio interference suppressers installed at the input power point. Interference suppressers shall be of a design which will minimize interference in both broadcast and aircraft frequencies, and shall provide a minimum attenuation of 50 decibels over a frequency range of 200 kilohertz to 75 megahertz when used in connection with normal installations. The interference filters furnished shall be hermetically sealed in a substantial case filled with a suitable insulating compound. Terminals shall be nickel plated, 10-24 brass studs of sufficient external length to provide space to connect two 8 AWG wires, and shall be so mounted that they cannot be turned in the case.

Ungrounded terminals shall be insulated from each other and shall maintain a surface leakage distance of not less than ½-inch between any exposed current conductor and any other metallic parts with an insulation factor of 100-200 megohms dependent on external circuit conditions.

Suppressers shall be designed for operations on 50 amperes, 125 volts, 60 cycles, single wire circuits, and shall meet standards of the Underwriters' Laboratories and the Radio Manufacturers Association.

#### **9-29.13(7) Traffic-Actuated Controllers**

All traffic signal controllers shall operate with industry standard operating software installed that at a minimum has the following:

1. Defined phases, minimum of 8 each.
2. Has manufacturer designed single or 2 ring operation minimum.
3. A minimum of four overlaps.
4. Defined intervals, min green, walk, flash don't walk, passage, gap, minimum gap, simultaneous gap out, volume density, yellow clearance, all red clearance, Maximum I, Maximum II.

Traffic-actuated controllers shall be electronic devices which, when connected to traffic detectors or other means of actuation, or both, shall operate the electrical traffic signal system at one or more intersections.

All solid-state electronic traffic-actuated controllers and their supplemental devices shall employ digital timing methods.

Control equipment shall conform to 9-29.13.

Actuated traffic signal controllers shall be 8-phase minimum control units. Volume-density timing features shall be provided on all controllers.

Every pin of every connecting plug shall be utilized as described within the NEMA requirement, except that those pins identified as “spare” or “future” shall remain unused. Controller interchangeability between NEMA controllers of any and all approved makes is mandatory, as is interchangeability of any and all approved makes of 170E, 2070, and 2070 Lite controllers every pin of every connecting plug shall be utilized as described within the 1999 Caltrans Specification.

Overlaps for NEMA controllers may be accomplished by programming of software or by use of NEMA overlap boards. If a manufacturer elects to utilize the software method, they may be required to furnish an overlap board with each signal controller which will allow substitution of controllers using the alternated method of overlaps.

NEMA controllers shall provide indications for vehicle call and pedestrian call that can be viewed simultaneously with indications for timing intervals. Controllers shall provide indications for timing intervals in both rings that can be viewed simultaneously. Reason for green termination shall be displayed simultaneously with other timing data.

All controllers shall provide a “simultaneous gap out” feature. This feature allows retiming a gap from a green rest upon an actuation.

#### **9-29.13(7)A Environmental, Performance, and Test Standards for Solid-State Traffic Controllers**

The scope of this Specification includes the controller assembly of solid-state design installed in a weatherproof controller cabinet. The controller assembly includes the cabinet, controller unit, load switches, signal conflict monitoring circuitry, accessory logic circuitry, AC line filters, vehicle detectors, coordination equipment and interface, and preemption equipment. NEMA control assemblies shall meet or exceed current NEMA TS 1 Environmental Standards. Normal operation will be required while the control assembly is subjected to any combination of high and low environmental limits (i.e. low voltage at high temperature with high repetition noise transients). All other control equipment testing shall be tested to Caltrans Transportation Electrical Equipment Specifications (TEES) dated November 19, 1999.

#### **9-29.13(7)B Auxiliary Equipment for NEMA Controllers**

The following auxiliary equipment shall be furnished and installed in each cabinet for NEMA traffic-actuated controllers:

1. A solid-state Type 3 NEMA flasher with flash-transfer relay which will cut in the flasher and isolate the controller from light circuits. See Section 9-29.13(2) for operational requirements.
2. Modular solid state relay load switches of sufficient number to provide for each vehicle phase (including future phases if shown in the plans), each pedestrian phase and preemption sequence indicated in the Contract. Type P & R cabinets shall include a fully wired 16-position back panel. Solid-state load

switches shall conform to NEMA standards except only optically isolated load switches will be allowed. Load switches shall include indicator lights on the input circuits. The controller cabinet shall have all cabinet wiring installed for eight vehicle phases, four pedestrian phases, four emergency pre-empts, four overlaps (OL A, B, C, D).

3. A power panel with:
  - a. A control-display breaker sized to provide 125 percent overload protection for all control equipment and signal displays, 30 ampere minimum.
  - b. A 20 ampere accessory breaker wired parallel to the control display breaker. The breaker will carry accessory loads, including vent fan, cabinet light, plug receptacle, etc.
  - c. A busbar isolated from ground and unfused for the neutral side of power supply.
  - d. A radio interference suppresser to the output side of the control display breaker. See Section 9-29.13(6) for other requirements.
  - e. A transient voltage protection device connected to the controller power circuit for protection against voltage abnormalities of 1 cycle or less duration. The protector shall be a solid state high energy circuit containing no spark gap, gas tube, or crow bar component. The current rating of the device shall be 15 amps minimum. The device shall provide transient protection between neutral and ground, line and ground, as well as line and neutral. If the protection circuits fail, they shall fail to an open circuit condition. The device shall meet all requirements of UL standard 1449. The suppressed voltage rating shall be 600 volts or less when subjected to an impulse of 6,000 volts, 3,000 amp source impedance, 8.0/20 microsecond waveform as described in UL 1449. In addition, the device shall withstand, without failure or permanent damage, one full cycle at 264 volts RMS. The device shall contain circuitry to prevent self-induced regenerative ringing. There shall be a failure warning indicator light which shall illuminate when the device has failed and is no longer operable.
  - f. Cabinet ground busbar independent (150K ohms minimum) of neutral.
4. A police panel located behind the police panel door with a flash automatic switch and a control-display power line on-off switch. See Section 9-29.13(2) for operational requirements.
5. An auxiliary control panel located inside the controller cabinet with a flash-automatic switch and a controller on-off switch. See Section 9-29.13(2) for operational requirements. A three wire 15 ampere plug receptacle with grounding contact and 20 ampere ground fault interrupter shall also be provided on the panel.
6. A conflict monitor conforming to NEMA standards. See Section 9-29.13(2) for operational requirements. The unit shall monitor conflicting signal indications at the field connection terminals. The unit shall be wired in a manner such that the signal will revert to flash if the conflict monitor is removed from service. Supplemental loads not to exceed 10 watts per monitored circuit or other means, shall be provided to prevent conflict monitor actuation caused by dimming or lamp burn-out. Supplemental loads shall be installed on the control

side of the field terminals. Conflict monitors shall include a minimum of one indicator light for each phase used. The monitoring capacity of the unit shall be compatible with the controller frame size. Conflict monitors shall include a program card.

7. A "Display Panel" when noted in the Contract. The display panel shall depict a generic eight-phase operation. The panel shall be mounted on the inside of the front cabinet door and the mounting shall be of a design that allows positioning of the panel in four orientations 90 degrees from each other. The mounting shall be removable without use of any tools. Incandescent red, yellow, green, walk and don't walk indicator lights shall be provided for each phase. The indicator lights shall be connected to the associated field terminals. The connecting cable shall be long enough to allow for any mounting orientation. No diodes will be allowed in the display panel. A means of disconnecting all wiring entering the panel shall be provided. Switches shall be provided on the panel with labels and functions as follows:
  - a. Display On — Signal indicator lamps will display the operation of the intersection.
  - b. Test — All indicator lamps shall be energized.
  - c. Display Off — all signal indicator lamps shall be de-energized.

A "Detector Panel", as specified in Standard Specification Section 9-29.12(7)D, shall be installed. The panel shall be mounted on the inside of the front cabinet door. The detector panel shall be constructed as a single unit. Detector switches with separate operate, test, and off positions shall be provided for each field detector input circuit. A high intensity light emitting diode (LED) shall be provided for each switch. The lamp shall energize upon vehicle, pedestrian or test switch actuation. The test switch shall provide a spring loaded momentary contact that will place a call into the controller. When in the OFF position, respective detector circuits will be disconnected. In the operate position, each respective detector circuit shall operate normally. Switches shall be provided on the panel with labels and functions as follows:

- a. Display On — Detector indicator lights shall operate consistent with their respective switches.
- b. Display Off — detector indicator lights shall be de-energized.

A means of disconnecting all wiring entering the panel shall be provided. The disconnect shall include a means to jumper detection calls when the display panel is disconnected. All switches on the panel shall be marked with its associated Plan detector number. All markers shall be permanent.

8. Insulated terminal blocks of sufficient number to provide a termination for all field wiring. A minimum of 12 spare terminals shall be provided. Field wire connection terminal blocks shall be 600 volt, heavy duty, barrier type, except loop detector lead-ins, which may be 300 volt. The 600 volt type-terminal strips shall be provided with a field-side and a control-side connector separated by a marker strip. The 300 volt type shall have a marker strip, installed on the right side of vertical terminal strips or below horizontal terminal strips. The marker strip shall bear the circuit number indicated in the plans and shall be engraved. Each connector shall be a screw type with No. 8 post capable of accepting no less than three 12 AWG wires fitted with spade tips.

9. A vent fan with adjustable thermostat. The minimum CFM rating of the fan shall exceed three times the cabinet volume.
10. An incandescent or fluorescent interior cabinet light mounted at the top of the enclosure with door switch to automatically energize when the door opens. The light shall be installed a minimum of 12-inches from the vent fan thermostat. The switch shall be labeled "light."
11. All wiring within the cabinet, exclusive of wiring installed by the signal controller manufacturer, shall have insulation conforming to the requirements of Section 9-29.3. Cabinet wiring shall be trimmed to eliminate all slack and shall be laced or bound together with nylon wraps or equivalent. All terminals, shall be numbered and permanently identified with PVC or polyolefin wire marking sleeve consistent with the cabinet wiring diagram provided by the signal controller manufacturer and the Contract. The cabinet will be completely wired so that the only requirement to make a field location completely operational is to attach field power and ground wiring. Internal cabinet wiring shall not utilize the field side connections of the terminal strip intended for termination of field wires.
12. One reproducible mylar or two microfilms and four copies of the cabinet wiring diagram and component wiring diagrams shall be furnished with each cabinet. Each cabinet shall be equipped with a, shelf mounted roll out drawer mounted directly below the controller to house one or more cabinet wiring diagrams. The cabinet wiring diagram shall indicate and identify all wire terminations, all plug connectors, and the locations of all equipment in the cabinet. Included in the diagram shall be an intersection sketch identifying all heads, detectors, and push buttons; and a phase diagram.
13. Each vehicle detector amplifier, video detection out put channel pedestrian call isolation unit, phase selector, discriminator, and load switch shall be identified with semi-permanent stick-on type label. The following information shall be included:
  - a. Vehicle Detector Amplifier Channel
    1. Loop number
    2. Assigned phase(s)
  - b. Ped Call Isolation Unit
    1. Push button number
    2. Assigned phase(s)
  - c. Load Switches
    1. Signal head number
    2. Assigned phase(s)
  - d. Phase Selectors
    1. Circuit Letter
    2. Phase(s) called

The label shall be placed on the face of the unit. It shall not block any switch, light, or operational words on the unit. The lettering on this label shall be neat, legible, and easily read from a distance of approximately 6-feet.

**9-29.13(7)C Auxiliary Equipment for Type 170E, 2070, 2070 Lite Assemblies**

The following requirements apply to required auxiliary equipment furnished with Type 170E, 170E-HC-11, 2070, 2070 Lite, ATC controller cabinets:

- A. Flashers, flash transfer relays, conflict monitor, AC isolators, DC isolators, discriminator modules, program modules, modem modules, load switches, breakers, buses, police panel switches, receptacle requirement, vent fan and auxiliary control panel switches shall conform to the requirements noted in the California Department of Transportation document entitled "Traffic Signal Control Equipment Specifications" specified in Section 9-29.13(7).
- B. Flashing operation shall conform to Section 9-29.13(2), except the 8-second flash period described in Item 2 of that section will not be required. Emergency preemption shall conform to Section 9-29.13(3).

The requirements for radio interference suppressor, transient voltage protection, terminal blocks, cabinet light (florescent only), cabinet wiring, wiring diagram and equipment labeling are the same as previously noted for the NEMA control assemblies.
- C. Input and output terminals shall be installed with a marking strip with field wire numbers noted in the Contract embossed on the strip. All cabinet and field conductor shall have a PVC or polyolefin wire marking sleeve installed, matching the input and output terminals above.
- D. The input panel terminal blocks TB 2 through TB 9 and associated cable to the input files as described in California Department of Transportation document entitled "Traffic Signal Control Equipment Specifications" dated November 19, 1999 shall be provided in all control assemblies. The alternate raceway specified in Chapter 18 will not be allowed.
- E. Supplemental load requirements to prevent conflict monitor actuation on lamp burnout are the same as previously noted for NEMA control assemblies.
- F. A "Display Panel", conforming to the requirements previously noted for the NEMA control assemblies shall be provided when noted in the Contract.
- G. A "Detection Panel" conforming to the requirements previously noted for the NEMA control assemblies shall be provided except the panel shall be a separate unit from the "Display Panel." The panel shall be rack mounted above the controller and shall conform to details in the Contract.
- H. A "Detector Termination and Interface Panel" shall be provided. When viewing the cabinet from the back, the panel shall be located on the upper left hand side of the cabinet. The panel shall be electrically located between the "Detector Panel" and the C-1 connector. The panel shall utilize insulated terminal blocks and each connector shall be a screw type with post.
- I. A print holder rollout drawer shall be provided. The drawer shall be rack mounted below the controller.
- J. A "DB-9" socket shall be mounted on the rack facing the front door of the cabinet and shall be easily accessible when the front door is open. The socket shall provide a communication interface between a personal computer and the C-20S connector on the back of the controller. The appropriate cable and C-20 plug connector shall be part of this assembly to provide ease of connection to the controller.

- K. A C-2 plug with 6-feet of 22 AWG 4 conductor shielded cable shall be provided in each cabinet. The cable shall be terminated on positions 3, 4, and 6 of the TB terminal block.
- L. An “Absence Of Red Programming Assembly” shall be provided. There shall be provided on the back panel of the output file, 16 accessible jumper plug attachment areas, made up of three male pins per position (one set of three, for each conflict monitor channel). Each jumper plug shall be a three position Molex style connector, using crimped wire pins. Two female pins shall be installed in each jumper plug, one attached to each end of a single wire. These pins shall be installed in the connector, one on the center position and one in either outer position of the plug. It shall be possible, by inserting and positioning one of the 16 jumper plugs on the right two pins on the monitor board, to apply 120 VAC into a corresponding channel of the conflict monitor red channels. The connection between the absence of red programming board and the 210 plus conflict monitor shall be accomplished via a 20 pin ribbon cable and the industry standard P-20 connector, that attaches on the front panel of the monitor. It shall be possible, by inserting and positioning one of the 16 jumper plugs on the two left pins on the monitor board, to enable the red monitor on the corresponding channel (phase). There shall be installed on the absence of red programming assembly a red enable disconnect relay, that controls the 120 VAC red enable signal into the 210 plus monitor. During normal operation, the normally closed contacts of this relay shall supply 120 VAC into the red enable input of the monitor. When energized, this red enable signal shall be removed from the input disabling red monitoring. The relay shall be energized by the corresponding CI pin connection, as required by the local software, to indicate that the assembly is in processor flash.
- M. Seven AC – copper neutral bars shall be installed in each 332, 336 controller cabinet, four 4 on the right side and three 3 on the left side. All of the neutral bars shall be secured per the current Caltrans Specification. All neutral bars shall be at the same electrical potential.

#### **9-29.13(7)D NEMA Controller Cabinets**

Each traffic-actuated NEMA controller shall be housed in a weatherproof cabinet conforming to the following requirements:

1. Construction shall be of 0.073-inch minimum thickness series 300 stainless steel or 0.125 minimum thickness 5052 H32 ASTM B209 alloy aluminum. The stainless steel shall be annealed or one-quarter-hardness complying with ASTM A666 stainless steel sheet. Cabinets may be finished inside with an approved finish coat of exterior white enamel. If no other coating is specified in the Contract Provisions the exterior of all cabinets shall be bare metal. All controller cabinets shall be furnished with front and rear doors.
2. The cabinet shall contain shelving, brackets, racks, etc., to support the controller and auxiliary equipment. All equipment shall set squarely on shelves or be mounted in racks and shall be removable without turning, tilting, or rotating or relocating one device to remove another. A 24 slot rack or racks shall be installed. The rack(s) shall be wired for 2 channel loop detectors and as follows. Slots 1 & 2 phase 1 loop detectors. Slots 3, 4, & 5 phase 2 loop detectors. Slots 6 & 7 phase 3 loop detectors. Slots 8, 9, & 10 phase 4 loop

detectors. Slots 11 & 12 phase 5 loop detectors. Slots 13, 14, & 15 phase 6 loop detectors. Slots 16 & 17 phase 7 loop detectors. Slots 18, 19 & 20 phase 8 loop detectors. Slot 21 upper phase 1 loop detector. Slot 21 lower phase 5 detector. Slot 22 wired for a 2 channel discriminator channels A, C. Slot 23 wired for a 2 channel discriminator, channels B, D. Slot 24 wired for a 4 channel discriminator, wired for channel A, B, C, and D. All loop detector slots shall be wired for presence/pulse detection/extension. If an external power supply is required in order for the entire racks(s) to be powered it shall be installed. All rack(s) slots shall be labeled with engraved identification strips.

3. Additional detection utilizing the “D” connector shall be installed in accordance with the Contract. The cabinet shall be of adequate size to properly house the controller and all required appurtenances and auxiliary equipment in an upright position with a clearance of at least 3-inches from the vent fan and filter to allow for proper air flow. In no case shall more than 70 percent of the cabinet volume be used. There shall be at least a 2-inch clearance between shelf mounted equipment and the cabinet wall or equipment mounted on the cabinet wall.
4. The cabinet shall have an air intake vent on the lower half of the front door, with a 12-inch by 16-inch by 1-inch removable throw away filter, secured in place with a spring-loaded framework.
5. The cabinet door(s) shall be provided with:
  - a. Spring loaded construction core locks capable of accepting a Best type CX series six segment (core installed by others) shall be installed in each door with the exception of the police panel door. Cabinet doors shall each have a three point latch system.
  - b. A police panel assembly shall be installed in the front door and shall have a stainless steel hinge pin and a police panel lock. Two police keys with shafts a minimum of 1¾-inches long shall be provided with each cabinet.
  - c. All doors and police panel door shall have one piece, closed cell, neoprene gaskets.
  - d. A two position doorstop assembly. Front and rear interior light control switches.

**9-29.13(7)E Type 170E, 170E-HC-11, 2070, 2070 Lite, ATC Controller Cabinets**

The above controllers shall be housed in a Models 332, Double 332, 336, 336S, 303 ITS/ATC cabinets, or as specified in the Contract. Each door shall be furnished with a construction core lock conforming to Standard Specifications 9-29.13 (7)D 5a, b and c above. A police panel with door, stainless steel hinge pin and lock shall be provided. Two police keys with shafts a minimum of 1¾” long shall be provided with each cabinet. Each of these cabinets shall be furnished with auxiliary equipment described in Standard Specification 9-29.13(7)C. Type 334 cabinets for traffic data station controller furnished shall meet current Caltrans 170E Specifications, as stated in Section 9-29.13(7) and as follows. Camera control and DMS local control cabinets shall contain the equipment shown in the Plans. The cabinet shall have the same external physical dimensions and appearance of Model 334 cabinets.

1. The cabinet shall be fabricated of stainless steel or sheet aluminum in accordance with Section 9-29.13(7)D, Item number 1. Painted steel, painted or anodized aluminum is not allowed.
2. Cabinet doors shall have a three-point latch and two-position stop assembly with spring loaded construction core lock capable of accepting a Best lock company type, with 6-pin CX series core. The Contractor shall supply construction cores. Upon Contract completion, the Contractor shall deliver two master keys to the Engineer.
3. Field wire terminals shall be labeled in accordance with the Field Wiring Chart.
4. A shatterproof fluorescent interior cabinet lights with self-starting ballast shall be furnished, one fixture mounted on the rear rack near the top and the second mounted at the top of the front rack. Door switches shall automatically turn on both lights when either door is opened.
5. One controller unit shelf, which attaches to the front rails of the EIA rack, shall be provided in lieu of the two controller unit support angles. The shelf shall be fabricated from aluminum and shall be installed such that it does not interfere with access to any terminal block. The shelf shall contain a rollout flip-top drawer for storage of wiring diagrams and manuals.

A disposable paper filter element of at least 180 square inches shall be provided in lieu of a metal filter.

All traffic data and ramp meter cabinets shall include the following accessories:

1. Each cabinet shall be equipped with a fully operable controller equipped as specified in the Contract Provisions.
2. Two input files, except on Type 303 and 336 cabinet shall be supplied, each using 133 millimeters of rack height.
3. Power Distribution Assembly shall be PDA #3 as detailed in the January 1989 Caltrans 170 Specification, with all current amendments.

The PDA #3 shall contain three Model 200 Load Switches.

A transient voltage protection device shall be provided, which plugs into the controller unit receptacle and in turn accepts the controller plug and meets the electrical requirements of Section 9-29.13(7)B(3) item e.

A second transfer relay, Model 430, shall be mounted on the rear of the PDA #3 and wired as shown in the Plans.

4. Police Panel shall contain only one DPDT toggle switch. The switch shall be labeled POLICE CONTROL, ON-OFF.
5. Display Panel
  - A. General

Each cabinet shall be furnished with a display panel. The panel shall be mounted, showing and providing detection for inputs and specified controller outputs, at the top of the front rack above the controller unit. The display panel shall be fabricated from brushed aluminum and constructed according to the detail in the Plans.

## B. Text

All text on the display panel shall be black in color and silk screened directly to the panel except the Phenolic detector and cabinet nameplates.

A nameplate for each loop shall be engraved with a 1/4-inch nominal text according to the ITS Field Wiring Charts. The nameplates shall be permanently affixed to the display panel.

## C. LEDs

The LEDs for the display panel shall meet the following Specifications:

Case size	T 1-3/4
Viewing angle	50° minimum
Brightness	8 Milli candelas

LEDs with RED, YELLOW or GREEN as part of their labels shall be red, yellow or green in color. All other LEDs shall be red. All LEDs shall have tinted diffused lenses.

## D. Detector Display Control Switch

Each display panel shall be equipped with one detector display control switch on the panel with labels and functions as follows:

ON

Detector display LEDs shall operate consistent with their separate switches.

OFF

All detector indicator LEDs shall be de-energized. Detector calls shall continue to reach the controller.

TEST

All detector indicator LEDs shall illuminate and no calls shall be placed to the controller.

## E. Advance Warning Sign Control Switch

Each display panel shall be equipped with one advance warning sign control switch on the panel with labels and functions as follows:

AUTOMATIC

Sign Relay shall energize upon ground true call from controller.

SIGN OFF

Sign Relay shall de-energize.

SIGN ON

Sign Relay shall energize.

## F. Sign Relay

The sign relay shall be plugged into a socket installed on the rear of the display panel. The relay shall be wired as shown in the Plans. The relay coil shall draw (or sink) 50 milliamperes  $\pm$  10% from the 170E controller and have a DPDT contact rating not less than 10 amperes. A 1N4004 diode shall be placed across the relay coil to suppress voltage spikes. The anode terminal shall be connected to terminal #7 of the relay as labeled in the Plans. The relay shall energize when the METERING indicator LED is lit.

G. Detector Input Indicators

One display LED and one spring-loaded two-position SPST toggle switch shall be provided for each of the 40 detection inputs. These LEDs and switches shall function as follows:

TEST

When the switch is in the test position, a call shall be placed to the controller and energize the associated LED. The switch shall automatically return to the run position when it is released.

RUN

In the run position the LEDs shall illuminate for the duration of each call to the controller.

H. Controller Output Indicators

The display panel shall contain a series of output indicator LEDs mounted below the detection indicators. The layout shall be according to the detail in the Plans. These LEDs shall illuminate upon a ground true output from the controller via the C5 connector.

The output indicator LEDs shall have resistors in series to drop the voltage from 24 volts DC to their rated voltage and limit current below their rated current. The anode connection of each LED to +24 VDC shall be wired through the resistor.

I. Connectors

Connection to the display panel shall be made by three connectors, one pin (labeled P2) and one socket (labeled P1) and one labeled C5. The P1 and P2 connectors shall be 50-pin cannon D series, or equivalent 50 pin connectors and shall be compatible such that the two connectors can be connected directly to one another to bypass the input detection. Wiring for the P1, P2 and C5 connectors shall be as shown in the Plans.

The Contractor shall install wire connectors P1, P2, C1P, C2, C4, C5 and C6 according to the pin assignments shown in the Plans.

6. Model 204 Flasher Unit

Each Model 334 ramp meter cabinet shall be supplied with one Model 204 sign flasher unit mounted on the right rear side panel. The flasher shall be powered from T1-2. The outputs from the flasher shall be wired to T1-5 and T1-6.

7. Fiber Optic Patch Panel

The Contractor shall provide and install a rack-mounted fiber optic patch panel as identified in the Plans.

**Cabinet Wiring**

Terminal blocks TB1 through TB9 shall be installed on the Input Panel. Layout and position assignment of the terminal blocks shall be as noted in the Plans.

Terminals for field wiring in traffic data and/or ramp metering controller cabinet shall be labeled, numbered and connected in accordance with the following:

Terminal Block Pos.	Terminal and Wire Numbers	Connection Identification
TBS	501-502	AC Power, Neutral
T1-2	641	Sign on
T1-4	643	Sign off
T1-5	644	Flasher Output NC
T1-6	645	Flasher Output NO
T4-1	631	Lane 3 - Red
T4-2	632	Lane 3 - Yellow
T4-3	633	Lane 3 - Green
T4-4	621	Lane 2 - Red
T4-5	622	Lane 2 - Yellow
T4-6	623	Lane 2 - Green
T4-7	611	Lane 1 - Red
T4-8	612	Lane 1 - Yellow
T4-9	613	Lane 1 - Green

Loop lead-in cables shall be labeled and connected to cabinet terminals according to the ITS Field Wiring Chart. This chart will be provided by the Engineer within 20 days of the Contractor's request.

#### **9-29.14 Vacant**

#### **9-29.15 Flashing Beacon Control**

Flashers shall conform to the latest NEMA publication, and shall be solid state. When used as a beacon control, they shall be jack mounted and installed in raintight aluminum or hot dipped galvanized steel cabinet.

#### **9-29.16 Vehicular Signal Heads**

Each signal head shall be of the adjustable, vertical type with the number and type of lights detailed in the Contract; shall provide a light indication in one direction only; shall be adjustable through 360 degrees about a vertical axis; and shall be mounted at the location and in the manner shown in the plans. Except for optically programmed signal heads, all vehicular signal heads at any one intersection shall be of the same make and type.

#### **9-29.16(1) Optically Programmed, Adjustable Face, 12-inch Traffic Signal**

The signal shall permit the visibility zone of the indication to be determined optically and require no hoods or louvers. The projected indication may be selectively visible or veiled anywhere within 15 degrees of the optical axis. No indication shall result from external illumination, nor shall one light unit illuminate a second. The display shall be maintained from 85 VAC to 130 VAC.

#### **9-29.16(1)A Optical System**

The components of the optical system shall comprise:

1. Lamp,
2. Lamp Collar,
3. Optical Limiter-Diffuser, and
4. Objective Lens.

The lamp shall be nominal 150 watt, 120 volt AC, three prong, sealed beam having an integral reflector with stippled cover and an average rated life of at least 6,000 hours. The lamp shall be coupled to the diffusing element with a collar including a specular inner surface. The diffusing element may be discrete or integral with the convex surface of the optical limiter.

The optical limiter shall provide an accessible imaging surface at focus on the optical axis for objects 900 to 1,200-feet distant, and permit an effective veiling mask to be variously applied as determined by the desired visibility zone. The optical limiter shall be provided with positive indexing means and composed of heat-resistant glass.

The objective lens shall be a high resolution planar incremental lens hermetically sealed within a flat laminant of weather resistant acrylic or approved equal. The lens shall be symmetrical in outline and may be rotated to any 90 degree orientation about the optical axis without displacing the primary image.

The optical system shall accommodate projection of diverse, selected indicia to separate portions of the roadway such that only one indication will be simultaneously apparent to any viewer after optically limiting procedures have been accomplished. The projected indication shall conform to ITE transmittance and chromaticity standards.

#### **9-29.16(1)B Construction**

Die cast aluminum parts shall conform to ITE alloy and tensile requirements and have a chromate preparatory treatment. The exterior of the signal case, lamp housing, and mounting flanges shall be finished with a high quality, baked enamel prime and finish paint.

The lens holder and interior of the case shall be optical black.

Signal case and lens holder shall be predrilled for backplates and visors. Hinge and latch pins shall be stainless steel. All access openings shall be sealed with weather resistant rubber gaskets.

Backplates shall conform to ITE material requirements and include a chromate preparatory treatment and optical black on all surfaces.

#### **9-29.16(1)C Mounting**

The signal shall mount to standard 1½-inch fittings as a single section, as a multiple section face, or in combination with other signals. The signal section shall be provided with an adjustable connection that permits incremental tilting of at least 0 degree to 10 degree above or below the horizontal while maintaining a common vertical axis through couplers and mounting. Terminal connection shall permit external adjustment about the mounting axis in five degree increments. The signal shall be mountable with ordinary tools and capable of being serviced with no tools.

Attachments such as visors, backplates, or adapters shall conform and readily fasten to existing mounting surfaces without affecting water and light integrity of the signal.

#### **9-29.16(1)D Electrical**

The lamp fixture shall be comprised of a separately accessible housing and integral lamp support, indexed ceramic socket, and self-aligning, quick release lamp retainer. The electrical connection between case and lamphousing shall be accomplished with an interlock assembly which disconnects lamp holder when opened. Each signal section shall include a covered terminal block for clip or screw attachment of lead wires. Concealed 18 AWG-AWM, stranded and coded wires shall interconnect all sections to permit field connection within any section.

**9-29.16(1)E Photo Controls**

Each signal section shall include integral means for regulating its intensity between limits as a function of individual background illumination. Lamp intensity shall not be less than 97 percent of uncontrolled intensity at 1,000 ft-c ambient and shall reduce to 15 plus or minus 2 percent of maximum at less than 1 ft-c ambient. Response shall be proportional and essentially instantaneous to any detectable increase of illumination from darkness to 1,000 ft-c ambient and damped for any decrease from 100 ft-c ambient.

The intensity controller shall comprise an integrated, directional light, sensing and regulating device interposed between lamp and line wires. It shall be compatible with 60 Hz input and responsive within the range 105 VAC to 135 VAC. Output may be phase controlled, but the device shall provide a nominal terminal impedance of 1,200 ohms open circuit and a corresponding holding current.

**9-29.16(1)F Installation**

The signal shall be installed, directed, and veiled in accordance with published instructions and the project visibility requirement. Each section of the signal shall be masked with prescribed materials in an acceptable and workmanlike manner.

**9-29.16(2) Conventional Traffic Signal Heads****9-29.16(2)A Optical Units**

Light Emitting Diode (LED) light sources are required for all red, yellow and green arrow or ball displays. LED light sources must conform to the current Vehicle Traffic Control Signal Heads, Part 2 (VTCSH2) ITE Specification dated January 13, 2004 and the following requirements: LED shall have a 50 degree min. viewing angle

1. Wattage (Maximum): 12-inch red, yellow and green ball displays - 25 W  
12-inch red, yellow and green arrow displays - 15W  
8-inch red, yellow and green ball displays - 15W
2. Voltage: The operation voltages shall be between 85 VAC and 130VAC.
3. The LED display shall be a module type and shall replace the lens, socket, bail, reflector and be directly connected to the terminal strip in the signal head.
4. Label: A label shall be provided on the LED housing. The Contractor shall mark the label with a permanent marker to note the installation date.

Incandescent light sources shall conform to the current Vehicle Traffic Control Signal Heads (VTCSH) ITE Specification and the following requirements:

1. Light Source: (8-inch Clear Bulb, A21/TS with brass medium base), (67 - 69 Watts), (12-inch clear bulb, P25/TS with brass medium base), (1650 lumens).
2. Voltage: 120 VAC.
3. Rated Initial Lumens at 120 VAC: (8-inch - 550), (12-inch- 1750).
4. Minimum Initial Lumens at 120 VAC: (8-inch - 550), (12-inch -1650).
5. Light Center: ( 8-inch, 2 7/16-inch), (12-inch, 3-inch).
6. Minimum Life: 8,000 hours.
7. Orientation: the bulb shall be installed with the opening between the filaments up.
8. Operation: The bulb shall operate properly form (-40°F to 170°F)
9. Lens: the lens material shall be prisms glass. The lens shall be secured to the housing with four noncorrosive clips and 4 No. 10 brass screws. The lens shall have a neoprene gasket making the display weather and dust tight.

10. Reflector: The reflector shall be specular aluminum with anodic coating.
11. Reflector Support: The reflector support shall be pivoted to the housing, and shall be designed so that it can be swung out or easily removed without the use of any tools.

#### **9-29.16(2)B Signal Housing**

The signal head housing, or case, shall consist of an assembly of separate sections, expandable type for vertical mounting, substantially secured together in a weathertight manner to form a unit of pleasing appearance. Each section shall house an individual optical unit.

Each section shall be complete with a one-piece, corrosion-resistant aluminum alloy die cast door and shall have a nominal 8-inch or 12-inch diameter opening for the lens. Each door shall be of the hinged type having two integrally cast hinge lugs and latch jaw. The door shall be attached to the housing by means of two noncorrosive, stainless steel hinge pins that are removable without the use of a special press or tool. A noncorrosive, stainless steel, threaded latch bolt and matching wing nut shall provide for opening and closing the door without the use of any special tools. Each door shall have a cellular neoprene gasket around the entire outer edge of the door, which, when the door is closed, shall make a positive weather and dust-tight seal. Each door shall have four tapped holes spaced about the circumference of the lens opening with four noncorrosive screws to accommodate the signal head visors. Each door shall have some device such as washers, clips, or keys, or be constructed so as to keep it from dismounting from the housing accidentally when it is open.

The body of each signal section shall consist of a one piece corrosion resistant, die cast aluminum alloy. Each section shall have serrated rings top and bottom so when used with proper brackets, each section may be adjustable in respect to an adjoining section, and the hangers may be locked securely to prevent moving. Cast integrally with the housing shall be two hinge lugs and one latch jaw. The top and bottom of the housing shall have an opening to accommodate standard 1½-inch pipe brackets. The sections shall be so designed that when assembled, they interlock with one another forming one continuous weathertight unit. The sections shall be interchangeable and shall be dust and weathertight when assembled with the door and appropriate furnished hardware.

A terminal block of an approved type shall be mounted inside at the back of the housing. All sockets shall be so wired that a white wire will be connected to the shell of the socket and a wire, the color of the lens, to the bottom, or end terminal of the socket. These wires shall in turn be connected to the terminal block mounted in the housing, in the proper manner. The terminal block shall have sufficient studs to terminate all field wires and lamp wires independently to the block with separate screws. The terminals to which field wires are attached shall be permanently identified to facilitate field work.

Each face shall be protected with a removable visor. The visor shall be tunnel type unless noted otherwise in the Contract. Tunnel, cap, and cut away type visors shall be molded using ultraviolet and heat stabilized polycarbonate plastic or be constructed of 0.050-inch corrosion resistant aluminum material throughout as specified in the Contract, or as ordered by the Engineer in accordance with Section 1-04.4. Visors shall be flat black in color inside and shall be flat black or dark green on the outside. Visors shall have attaching ears for installation to the housing door. The signal display shall have square doors. End caps shall be made from aluminum or plastic material and shall be installed with fittings to provide a watertight seal. A bead of silicone sealant shall be

applied around the perimeter of all top end cap openings prior to installation of the end cap assembly. Plastic end caps shall utilize a threaded stud with seal and wing nut. Plastic end caps utilizing a metal screw that may damage the cap if overtightened will not be allowed. Plastic end caps shall have the same color as the signal housing.

#### **9-29.16(2)C Louvered Visors**

Where noted in the Contract, louvered tunnel visors shall be furnished and installed. Directional, Geometrically Programmed louvers shall be constructed to have a snug fit in the signal visor. Louvers shall be flat black, constructed of aluminum or ABS and polycarbonate plastic. Dimensions and arrangement of louvers shall be as shown in the Contract.

#### **9-29.16(2)D Back Plates**

Back plates shall be furnished and attached to the signal heads. Back plates shall be constructed of 5-inch wide .050-inch thick corrosion resistant flat black finish, louvered aluminum or as specified in the Contract.

#### **9-29.16(2)E Painting Signal Heads**

Traffic signal heads shall be finished with two coats of factory applied dark green (Federal Standard 595B) baked enamel or shall be finished with a dark green oven baked powder coating comprised of resins and pigments. Aluminum end caps shall be painted to match the color of the signal housing.

#### **9-29.16(3) Polycarbonate Traffic Signal Heads**

Polycarbonate signal heads shall be provided only when specifically identified in the Contract. With the exception of top and bottom bracket mountings, polycarbonate signal heads shall be installed with approved reinforcing plates located in signal sections adjacent to the mounting hardware.

#### **9-29.16(3)A 8-inch Polycarbonate Traffic Signal Heads**

Polycarbonate employed in traffic signal fabrication shall tolerate an elongation prior to break in excess of 90 percent. The green color shall be molded throughout the head assembly. Glass lenses shall be employed in the signal heads. The optical system shall be of the fixed focus type for 67 to 69 watt bulbs. The entire optical system shall be sealed by a single neoprene gasket. Alzak aluminum reflectors will be permitted in polycarbonate traffic signal head assemblies. The signal head shall be formed to be used with standard signal head mounting accessories. The optical system shall be consistent with ITE requirements. All hinge pins, latch assemblies and reflector assemblies shall conform to 9-29.16(2)B.

#### **9-29.16(3)B 12-inch Polycarbonate Traffic Signal Heads**

Twelve inch polycarbonate signal heads shall conform to all requirements of the 8-inch polycarbonate signal heads except the optical system shall be designed for a 1750 lumen traffic signal lamp.

#### **9-29.17 Signal Head Mounting Brackets and Fittings**

Vehicle and pedestrian signal head mountings shall be as detailed in the Standard Plans. Material requirements for signal head mounts are as follows:

**Aluminum**

1. Hinge fittings for Type E mount.
2. Arms and slotted tube fittings for Type N mount.
3. Tube clamp and female clamp assembly for Type N mount.

**Bronze**

1. Terminal compartments for Type A, B, C, F, H, and K mounts.
2. Collars for Type C, D, and F mounts.
3. Ell fittings for Type L and LE mounts.
4. Plumbizer for type M mounts
5. Messenger hanger and wire entrance fittings for Type P, Q, R, and S mounts.
6. Balance adjuster for Type Q, R, and S mounts.

**Galvanized Steel**

1. Washers for Type A, B, C, D, F, H, and K mounts.
2. Fasteners for Type A, B, E, H, and K mounts.

**Stainless Steel**

1. All set screws and cotter Keys.
2. Bands for Type N mount.
3. Hinge pins for Type E mount.
4. Bolts, nuts and washers for Type M mount.
5. Bolt, nut and washers for Type L mount.
6. Bolts, nuts, washers, and screw buckle swivels.

**Steel**

1. Center pipes, nipples, elbow and tee fittings for Type A, B, C, F, H, and K mounts.
2. Multi-head mounting assemblies and spider assemblies for Type Q, R, and S mounts.
3. Nipples for Type L, LE, P, Q, R, and S mounts.

Fittings for Type N mounts shall be installed unpainted. All other hardware for other mounts shall be painted with two coats of factory applied traffic signal green baked enamel.

Pins for messenger hanger fittings shall be a minimum of ½-inch in diameter.

Terminal compartments for Type A, B, C, F, H, and K mounts shall contain a 12 section terminal block.

**9-29.18 Vehicle Detector**

Induction loop detectors and magnetometer detectors shall comply with current NEMA Specifications when installed with NEMA control assemblies and shall comply with the current California Department of Transportation document entitled "Transportation Electrical Equipment Specifications," specified in Section 9-29.13(7) when installed with Type 170 2070, 2070 Lite, ITS/ATC control assemblies.

**9-29.18(1) Induction Loop Detectors**

When required in the Contract, amplifier units shall be provided with supplemental timing features identified as follows:

1. Delay Timing. When delay timing is required, the unit shall delay detector output for up to 15 seconds minimum, settable in one second maximum intervals.
2. Delay Timing With Gate. When delay timing with gate is required, the unit shall provide delay timing features as noted above with the additional capability of inhibiting delay timing when an external signal is applied.
3. Extension Timing. When extension timing is required, the unit shall extend the detector output for up to 7 seconds minimum, settable in 0.5 second minimum intervals.
4. Delay and Extension Timing With Gate. When delay and extension timing with gate is required, the unit shall provide both delay and extension timing features as noted above with the additional capability of inhibiting delay while enabling extension upon application of an external signal. Without external signal, the unit shall inhibit extension and enable delay.

#### **9-29.18(2) Magnetometer Detectors**

Magnetometer detector units and sensors shall conform to the following Specifications:

1. Operation. The magnetometer detector unit shall respond to changes in the earth's local magnetic field caused by the passage of a vehicle containing iron or steel over the sensor unit.
2. Environmental Requirements. Satisfactory operation shall be attained over the ambient temperature range from -30°F to 160°F. Operation shall be unaffected by temperature change, water, ice, pavement deterioration, or electromagnetic noise.
3. Modes of Operation. Each detector channel shall be capable of functioning in any of four front-panel selectable modes:
  - a. Presence. Time of detection shall be unlimited.
  - b. Extended Presence. The detection output shall extend for a timer set value of up to 5 seconds after the detection zone has cleared.
  - c. Pulse. A single 30 to 50 millisecond pulse will be generated per detection actuation.
  - d. Inhibited Pulse. The detection output will be inhibited for a time set value of up to 5 seconds after the detection zone has cleared.
4. Response Time. Pick up and drop out times shall be consistently within 10 milliseconds.
5. Approach Speed. The unit shall be capable of detecting vehicles traveling from 0 to 80 miles per hour.
6. Sensor Probes. Each channel of the detector unit shall be capable of operating up to three sensing probes.

#### **9-29.19 Pedestrian Push Buttons**

Where noted in the Contract, pedestrian push buttons of substantially tamper-proof construction shall be furnished and installed. They shall consist of a 2-inch nominal diameter plunger and a momentary contact switch assembled with the push button sign shown in the plans. The switch may have magnetic, or piezoelectric switch, or actuated by a three bladed beryllium copper spring, and shall be rated 10 amperes, 125 volts.

The plunger may have an LED to indicate that a pedestrian call has been registered.

The pedestrian push-button assembly shall be constructed and mounted as detailed in the Contract.

#### **9-29.20 Pedestrian Signals**

Pedestrian signals shall be either neon-grid type, or LED as specified in the Contract. Pedestrian signals shall conform to ITE Standards (Standard for Adjustable Face Pedestrian Signal Heads, 1975).

The Pedestrian signal heads shall be on the QPL or A Certificate of Compliance shall be submitted by the manufacturer with each type of signal head. The certificate shall state that the lot of pedestrian signal heads meets the following requirements:

- A. All pedestrian signal heads shall be Neon Grid type or Light Emitting Diode (LED) or LED Walk/Don't Walk module.
- B. All pedestrian displays shall comply with ITE publication ST 011B, VTCSH2 or current ITE Specification, and the current draft or adopted Caltrans pedestrian LED displays and following requirements:
  - (1) All pedestrian signals supplied to any one project shall be from the same manufacturer and type but need not be from the same manufacturer as the vehicle heads.
  - (2) Word messages, when specified, shall provide letters a minimum of 4½-inches high. Symbol messages, when specified, shall be a minimum of 12-inches high and 7-inches in width.
  - (3) Housings shall be green polycarbonate or die-cast aluminum and the aluminum housings shall be painted with two coats of factory applied traffic signal green enamel (Federal Standard 595B). All hinges and latches and interior hardware shall be stainless steel.

#### **9-29.20(1) LED Pedestrian Displays**

Optical units for traffic signal displays shall conform to the following:

1. Light emitting diode (LED) light sources are required for 12-inch Portland Orange Hand and may be installed for the Lunar White Walking Man. LED displays shall conform to the following:
  - a. Wattage (Maximum): 12-inch Portland Orange Hand 15 watts 12-inch Lunar White walking Man 15 watts
  - b. Voltage: The operating voltages shall be between 85 VAC and 135 VAC.
  - c. Temperature: Temperature range shall be -35° F to +165° F.
  - d. LEDs shall be driven at no more than 50% of their rated amperage.
  - e. 12-inch Portland Orange Hand Circuit Configuration:
    1. LEDs shall be connected to form multiple series circuits, with a minimum of 2 circuits. All series circuits shall be interconnected at intervals forming subcircuits not exceeding 15 LEDs each. These subcircuits shall limit the number of extinguished LEDs to no more than 10% of the total on the display in the event of a single LED failure.

- f. 12-inch Lunar White Walking Man 1 Circuit Configuration: LEDs shall be connected to form multiple series circuits, with a minimum of 1 circuits. All series circuits shall be interconnected at intervals forming subcircuits not exceeding 15 LEDs each. These subcircuits shall limit the number of extinguished LEDs to no more than 10% of the total on the display in the event of a single LED failure.
- g. Color testing shall be conducted after 30 minutes of continuous operation.
- h. LED pedestrian heads shall be supplied with Z crate visors. Z crate visors shall have 21 members at 45 degrees and 20 horizontal members.

#### **9-29.20(2) Neon Grid Type**

Neon grid pedestrian heads shall be solid state type and shall be supplied with Z crate visors. Z crate visors shall have 21 members at 45 degrees and 20 horizontal members.

Neon tubing shall be enclosed and shock-mounted inside a rugged plastic module. The unit shall be 1½-inches deep. Members shall be constructed of 0.03-inch thick black polycarbonate plastic.

A combination switch/fuse holder shall be provided for each transformer. Each unit shall provide a grounding terminal.

Transformers shall provide recessed secondary contacts and integral Pyrex glass electrode housing.

#### **9-29.21 Flashing Beacon**

Flashing beacons shall be installed as detailed in the Plans, as specified in the Special Provisions, and as described below:

Controllers for flashing beacons shall be as specified in Section 9-29.15.

Beacons shall consist of single section, 8-inch or 12-inch traffic signal heads, three or four-way adjustable, meeting all of the applicable requirements of Section 9-29.16. Displays (red or yellow) may be either LED type or incandescent. 12-inch yellow displays shall be dimmed 50% after dark.

Mounting brackets, mountings, and installation shall meet all applicable requirements of Section 9-29.17.

Lenses shall be either red or amber, glass or polycarbonate as noted in the Plans.

#### **9-29.22 Vacant**

#### **9-29.23 Vacant**

#### **9-29.24 Service Cabinets**

In addition to the requirements for service cabinets indicated in the Contract, the following requirements shall apply:

- A. All electrical conductors, buss bars, and conductor terminals shall be copper. Conductor insulation shall be either THW, XHHW, USE, or SIS.
- B. If field wiring larger than that which the contactors or breakers will accommodate is required by the Contract, a terminal board shall be supplied for use as a splicing block.

- C. The minimum size of all other load carrying conductors used within the service cabinets shall be based on the National Electrical Code ampacity tables for not more than three conductors in a raceway or cable.
- D. Type B, B Modified, C, D, and E Cabinets shall have ventilation louvers on the lower sides complete with screens. Type D, and E shall also have rain-tight cabinet vents with screens at the top. Cabinet vents shall be gasketed.
- E. The Type B modified cabinets shall have one future use double pole circuit breaker. Type D, and E cabinets shall have two future use double pole circuit breakers. The dead front cover shall have cutouts with for all circuits. The receptacle shall be ground fault interrupter equipped.
- F. The minimum size of control circuit conductors used in service cabinets shall be 14 AWG stranded copper.  
All electrical contactors shall have the loadside terminals toward the front (door side) of the service cabinet.
- G. The lighting contactors used shall be specifically rated for tungsten fluorescent and mercury arc lamp loads.
- H. All service enclosures shall be fabricated from steel or aluminum. If aluminum, they shall be fabricated from 0.125-inch (minimum) 5052 H 32 ASTM designator or B209 aluminum. If steel, they shall be fabricated from 12 gage (minimum) steel, hot dipped galvanized per AASHTO M 111.
- I. All doors and dead front panels installed in service cabinets shall incorporate a hinge placed in a vertical plane. Service doors shall be sealed with closed cell gasket material. The side opposite the hinge shall be secured with quarter turn screws or slide latch. No electrical devices shall be connected to the dead front panel. However, every switch serviced through the dead front panel shall be appropriately identified with its respective circuit designation by means of a screwed or riveted engraved name plate. Such circuit identification shall be submitted for approval together with the appropriate fabrication drawings. Dead front panels shall be intended to provide security only to the switching segment of the service enclosure and shall not cover the electrical contactor portion.
- J. A typed index of all circuits shall be mounted on the cabinet door. Each index shall show an entire panel section without folding. Index holders shall have metal returns on the sides and bottom. A schematic of the main panel, any subpanels, circuits, and control circuits shall be provided. The schematic shall be plastic coated and secured in a metal holder.

#### **9-29.24(1) Vacant**

#### **9-29.24(2) Electrical Circuit Breakers and Contactors**

Lighting contactors shall be rated 240 volts maximum line to line, or 277 volt maximum line to neutral voltage for tungsten and ballasted lamp loads on 120/240/277 volt circuits, whichever is applicable, or they shall be rated 480 volt maximum line to line voltage for higher than 277 volt circuited tungsten or ballasted lamp loads.

As an alternate to the lighting contactor, the Contractor may furnish a double contact mercury relay. The relay ampere rating shall equal or exceed the rating noted in the Contract. The relay shall be normally open and shall be rated for up to 480 VAC resistive. The unit shall have a molded coil enclosure rated for 120 VAC. The contacts shall be

evacuated, backfilled with an inert gas and shall be hermetically sealed. The electrode shall be one piece with Teflon wear rings on the internal plunger assembly. All contact terminals and coil connection clamps shall be U.L. approved.

Circuit breakers shall be 240 or 277 volt maximum rated for 120/240/277 volt circuits, whichever is applicable, and shall have an interrupting capacity (R.M.S. — symmetrical) of not less than 10,000 amperes. They shall have not less than 480 volt rated for circuits above 277 volts and shall have an interrupting capacity (R.M.S. — symmetrical) of not less than 14,000 amperes. Circuit breakers shall be bolt-on type.

### 9-29.25 Amplifier, Transformer, and Terminal Cabinets

Amplifier, terminal, and transformer cabinets shall conform to the Contract, NEMA 4 requirements and the following:

1. All cabinets shall be constructed of welded 14 gage (minimum) hot dipped galvanized sheet steel, 14 gage, minimum type 316 stainless steel or 0.125-inch, minimum 5052 alloy aluminum H32 ASTM designator minimum.
2. Nominal cabinet dimensions shall be:
 

	Depth	Height	Width
a. Terminal	8"	16"	12"
b. Terminal	8"	24"	18"
c. Transformer Up to 3.0 KVA	12"	18"	18"
Transformer 23.1 to 12.5 KVA	20"	40"	24"
Transformer 12.6 to 35 KVA	30"	60"	32"
3. Cabinet doors shall be gasketed with a one-piece closed cell neoprene gasket and shall have a stainless steel piano hinge. The door shall also be provided with a three point latch and a spring loaded construction core lock capable of accepting a Best six pin CX series core. The locking mechanism shall provide a tapered bolt. The Contractor shall supply construction cores with two master keys. The keys shall be delivered to the engineer.
4. All seams shall be continuously welded.
5. All cabinets shall provide a door flange.
6. Transformer cabinets shall provide a 9 square inch minimum louvered vent.
7. One spare 12-position terminal block shall be installed in each terminal cabinet and amplifier cabinet.
8. Each Terminal, Amplifier and Transformer cabinet shall have 1/8-inch drain holes in back corners.
9. Mounting shall be as noted in the Contract.
10. Transformer cabinets shall have two separate compartments, one for the transformer and one for the power distribution circuit breakers. Each compartment shall be enclosed with a dead front. Each breaker shall be labeled with the device name.