SECTION 932
NONMETALLIC ACCESSORY MATERIALS
FOR CONCRETE PAVEMENT AND CONCRETE STRUCTURES

932-1 Joint Materials.

932-1.1 Preformed Joint Filler for Pavement and Structures: Preformed joint filler shall meet the requirements of AASHTO M 153, ASTM D8139, AASHTO M 213, or cellulose fiber types meeting all the requirements of AASHTO M 213 (except for the asphalt content) is acceptable provided they contain minimums of 0.2% zinc borate as a preservative and 1.5% waterproofing wax. For AASHTO M 153, unless a particular type is specified, either Type I, Type II or Type III may be used.

Preformed joint fillers shall have a thickness equal to the width of the joint required, and shall be furnished in lengths equal to the widths of the slabs in which they are to be installed, except strips which are of a length not less than the distance between longitudinal joints, or between longitudinal joint and edge, may be used if laced or clipped together in a manner approved by the Engineer. The depth and shape of the joint filler shall conform to the dimensions shown in the Plans. For doweled joints, proper provision shall be made for the installation of the dowels.

932-1.1.1 Certification: The Contractor shall submit to the Engineer a certification confirming that the preformed joint filler meets the requirements of this Section. The certification shall conform to the requirements of Section 6.

932-1.2 Joint Sealer for Pavement and Structures:

932-1.2.1 General: This Specification covers joint sealer intended for use in sealing joints in asphaltic concrete pavement and portland cement concrete pavement. These materials may also be used to seal joints in portland cement concrete bridges and other structures.

932-1.2.2 Material: The joint sealant shall be composed of a mixture of materials, typically but not limited to bituminous based, that will melt when heated for application and then solidify to form a resilient and adhesive compound capable of sealing joints in portland cement concrete and asphaltic concrete against the infiltration of moisture and foreign materials throughout normal pavement conditions and at ambient temperatures. The manufacturer shall have the option of formulating the material according to their Specifications. However, the requirements delineated in this Specification shall apply regardless of the type of formulation used. The material shall cure sufficiently to not flow from the joint or be picked up by vehicle tires after 3 hours at 77°F. The material shall be capable of a uniform application consistency suitable for filling joints without the inclusion of large air holes or discontinuities and without damage to the material.

Materials for pavement joints shall be tested according to ASTM D5329.

932-1.2.2.1 Physical Requirements of Joint Sealants for Portland Cement Concrete Only:

Table 932-1	
Parameter	Limits
Pour Point	At least 20°F lower than the safe heating temperature as stated by the manufacturer.
Cone-Penetration, Non-immersed at 77°F, 150 g, 5 s	Less than or equal to 90 mm
Flow at 140°F, 5 h	Less than or equal to 5.0 mm
Bond, Non-immersed, 0°F for 5 cycles*	No cracking, separation, or opening that at any point is over 1/4 inch deep, in the sealant or between the sealant and the substrate.
*The depth of a crack, separation or opening shall be measured perpendicular to the side of the sealant showing the defect. At least two test samples in a group of three representing a given sample of sealant shall meet this requirement.	

932-1.2.2.2 Physical Requirements of Joint Sealants for Portland Cement Concrete and/or Asphaltic Concrete:

Table 932-2	
Parameters	Limits
Pour Point	At least 20° lower than the safe heating temperature as stated by the manufacturer.
Cone-Penetration, Non-immersed at 77°F, 150 g, 5 s	Less than or equal to 90 mm
Flow at 140°F, 5 h	Less than or equal to 3.0 mm
Bond, Non-immersed, -20°F for 3 cycles, 50% extension*	No cracking, separation, or opening that at any point is over 1/4 inch deep, in the sealant or between the sealant and the substrate.
Resilience at 77°F	Recovery greater than or equal to 60%
Asphaltic Concrete Compatibility at 140°F	No failure in adhesion, formation of an oily exudates at the interface between the sealant and the asphaltic concrete, or softening or other deleterious effects on the asphaltic concrete or sealant.
*The depth of a crack, separation or opening shall be measured perpendicular to the side of the sealant showing the defect. At least two test samples in a group of three representing a given sample of sealant shall meet this requirement.	

932-1.2.3 Approved Product List (APL): The joint sealant materials used shall be one of the products listed on the Department's APL. Manufacturers seeking evaluation of their products shall submit product datasheets, performance test reports from an independent laboratory showing the product meets the requirements of this section, and an APL application in accordance with Section 6. Information on the APL application must identify the sealant type.

932-1.2.4 Shipment: The material shall be delivered in containers plainly marked with the manufacturer's name or trademark product name, LOT number and date of expiration.

932-1.2.5 Bond Breaker Rod: The bond breaker rod shall be a closed cell, expanded polyethylene foam rod of the size and dimensions shown in the Plans. It shall be compatible with the joint sealant and no bond or reaction shall occur between the rod and the sealant.

All bond breaker rods installed shall be covered by a sealant at the end of each workday.

Bond breaker tape approved by the sealant manufacturer may be used in lieu of bond breaker rod when sealing random cracks.

932-1.3 Low Modulus Silicone Sealant Materials:

932-1.3.1 Low Modulus Silicone Sealants: Silicone sealant shall be furnished in a one part or pre-measured two-part formulation meeting the requirements specified herein.

Acetic acid cure sealants are not acceptable. A primer as specified in 932-1.4 for bonding sealant to concrete shall be used if required by the manufacturer. When a manufacturer's product is tested and approved by the Department using a primer, primer will be required for project installation.

Do not use Low Modulus Silicone Sealants Types A, B or C for bridge expansion joints.

Silicones shall be identified in the following manner:

Type A - A low modulus, non-sag (non-self-leveling) silicone formulation, used in sealing horizontal and vertical joints in cement concrete pavements and bridges (i.e., concrete-concrete joints). Tooling is required.

Type B - A very low modulus, self-leveling silicone formulation, used in sealing horizontal joints (including joints on moderate slopes) in cement concrete pavements and bridges (i.e., concrete-concrete joints). Tooling is not normally required.

Type C - An ultra-low modulus, self-leveling silicone formulation, used in sealing horizontal joints (including joints on moderate slopes) in cement concrete pavements and bridges (i.e., concrete-concrete joints). It can also be used to seal the joints between cement concrete pavements and asphalt concrete shoulders (including asphalt-asphalt joints). Tooling is not normally required.

Type D - An ultra-low modulus, self-leveling silicone formulation, cold-applied, rapid-cure, used to seal expansion joints that experience both thermal and/or vertical movements. The material must cure by chemical reaction and not by evaporation of solvent or fluxing of harder particles. Tooling shall not be required. Use in accordance with Standard Plans, Index 458-110 for bridge deck expansion joints with backer rods or as shown in the Plans for other joints with or without backer rods.

932-1.3.2 Physical Requirements:

Table 932-3

Silicone Sealant Type	Test Method	Type A	Type B	Type C	Type D
Flow	ASTM D5893	No Flow			
Slump (maximum)	ASTM D2202	0.3 inches			
Extrusion rate (minimum)	ASTM C1183, Procedure A	20 ml/min	20 ml/min	20 ml/min	20 ml/min
Tack-free time at 77 ± 3ºF and 45 to 55% Relative Humidity	ASTM C679	90 minutes maximum	180 minutes, maximum	180 minutes, maximum	20 – 60 minutes
Specific gravity	ASTM D792, Method A	1.1 to 1.515	1.10 to 1.40	1.1 to 1.5	1.26 to 1.34
Durometer hardness, Shore A (Cured seven days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	ASTM D2240	10-25			

Table 932-3					
Silicone Sealant Type	Test Method	Type A	Type B	Type C	Type D
Durometer hardness, Shore 00 (Cured 21 days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	ASTM D2240		40-80	20-80	
Tensile stress (maximum) at 150% elongation	ASTM D412 (Die C)	45 psi	40 psi	15 psi	
Elongation (Cured seven days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	ASTM D412 (Die C)	800% minimum			600% minimum
Elongation (Cured 21 days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	ASTM D412 (Die C)		800% minimum	800% minimum	
Ozone and Ultraviolet Resistance	ASTM C793	No chalking, cracking or bond loss after 5,000 hours, minimum.			
Bond to cement mortar briquets (primed if required) (Cured seven days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	AASHTO T 132	50 psi minimum			
Bond to cement mortar briquets (Cured 21 days at 77 ± 3ºF and 50 ± 5% Relative Humidity)	AASHTO T 132		40 psi minimum	35 psi minimum	
Movement Capability	ASTM C719	No adhesive or cohesive failure and adhesion, 10 cycles at -50 to +100%			No adhesive or cohesive failure and adhesion, 10 cycles at +100/-50 %

Portland Cement Mortar: Briquets shall be molded and cured 28 days minimum in accordance with AASHTO T 132. Saw cut cured briquets in half, clean, and dry at 230°, plus or minus 5ºF. Bond the two halves together with a thin section of sealant. After cure of sealant, briquets shall be tested in accordance with AASHTO T 132.

932-1.3.3 Field Cure: Six-inch samples of the sealant shall be taken by the Engineer from the joint at the end of a two-week curing period and tested for durometer hardness (by FM ANSI/ASTM D2240), except that the requirements of a 1-inch sample width shall not apply. A minimum hardness of 7.0 is required as evidence of adequate cure.

932-1.3.4 Approved Product List: The low modulus silicone sealant used shall be one of the products listed on the APL. Manufacturers seeking evaluation of their products shall submit product datasheets, performance test reports from an independent laboratory

showing the product meets the requirements of this Section, an infrared identification curve (2.5 to 15 µm) and an APL application in accordance with Section 6. Information on the APL application must identify the sealant type.

932-1.3.5 Shipment: The material shall be delivered in containers plainly marked with the manufacturer's name or trademark product name, LOT number and date of expiration.

932-1.3.6 Primer: When required by the manufacturer's product, a primer shall be used.

The manufacturer shall perform quality control tests on each LOT of sealant primer material furnished to each project and submit a certified report that each LOT of primer material furnished to a project meets the company's specifications for that product and the primer is suitable for its intended use.

Sealant primer material shall be delivered in containers plainly marked with the manufacturer's name or trademark and product name, LOT number and date of expiration.

932-1.3.7 Backer Rod and Tape Bond Breakers: Backer rods and tape shall be compatible with the joint sealant and approved by the sealant manufacturer. No bond or reaction shall occur between the rod and the sealant.

932-1.3.8 Installation: Installation, material selection, joint dimensions, bond breaker suitability (by type and project) shall be in agreement with the requirements of Standard Plans, Indexes 350-001 and 458-110. Any modifications or exceptions to these requirements shall be shown in the Plans.

For new construction projects or general use where the joints to be sealed have uniform width, a closed cell, expanded polyethylene foam backer rod bond breaker shall be required. For rehabilitation projects and similar joint seals where the joints to be sealed have irregular width, an open cell, expanded polyethylene foam backer rod bond breaker with an impervious skin shall be required.

The backer rod shall be compatible with the joint sealant. No bond or reaction shall occur between the rod and the sealant.

Tape bond breaker approved by the sealant manufacturer may be used in lieu of backer rod bond breaker when sealing joints and/or random cracks, as required.

Type D Silicone sealant shall be placed when the ambient temperature is rising and is between 55°F and 85°F and the temperature is expected to rise for the next three hours minimum to provide to adequate joint opening and compression of the sealant during curing.

All installed bond breakers shall be covered by sealant at the end of each workday.

A tolerance in cross-sectional height at midpoint of minus 1/16 inches to plus 3/16 inches will be allowed to the nominal values shown for each joint width on the plan sheet. The Engineer shall check one joint for each 1,000 feet of roadway by cutting out specimens. If the cross section of the cut specimen is out of the allowable range, additional specimens shall be taken as follows:

One joint every 100 feet of pavement, not to exceed 500 feet.

If the average of the specimens is out of tolerance, the Contractor shall remove and replace the entire 500-foot section at no additional expense to the Department.

Installation tolerance shall be verified at 1,000-foot intervals.

932-1.4 Pre-cured Silicone Sealant:

932-1.4.1 General: Pre-cured silicone sealants are intended for sealing vertical joints on concrete surfaces. Type V1 sealant is intended for contraction joints or joints with movements less than 1/4 inches. Type V2 sealant is intended for expansion joints not exceeding 200% of the nominal joint opening. Type V2 sealant may be substituted for Type V1 sealant. The joint sealant must be listed on the APL.

932-1.4.2 Physical Requirements: Sealant material shall be a nominal 1/16 inches thick, available in standard widths from 1 inch to 6 inches, colored to match the finish surface coating of the concrete, and meet the following minimum testing requirements:

Table 932-4

Test Property Description	Test Method	Type V1	Type V2
Minimum Movement, Cohesion/Adhesion	ASTM C1523	100%	200%
Dry/Room Temperature Loss of Adhesion/Cohesion	ASTM C1523	None	None
Water Immersion Loss of Adhesion/Cohesion	ASTM C1523	None	None
Frozen Loss of Adhesion/Cohesion	ASTM C1523	None	None
Heat Loss of Adhesion/Cohesion	ASTM C1523	None	None
Artificial Weathering Loss of Adhesion/Cohesion	ASTM C1523	None	None
Tear Propagation	ASTM C1523	NT or PT (No Tear or Partial/Knotty Tear)	NT or PT (No Tear or Partial/Knotty Tear)
Ultimate Elongation	ASTM D412	250%	500%

932-1.4.3 Approved Product List: The pre-cured silicone sealant used shall be one of the products listed on the APL. Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6. Applications must include test results, an infrared identification curve (2.5 to 15 µm), and a product data sheet with the recommended adhesive and installation requirements.

932-1.5 Compression Seals and Adhesive Lubricant

932-1.5.1 Preformed Elastomeric Compression Seals: Preformed Elastomeric Compression Seals shall meet the requirements of ASTM D2628 except that immersion oil IRM 903 may be substituted for Oil No. 3 in the Oil Swell test procedure.

932-1.5.2 Compression Seal Adhesive Lubricant: Compression seal adhesive lubricant shall meet the requirements of ASTM D4070. The material shall be fluid from 5°F to 120°F (-15°C to 49°C).

932-1.5.3 Certification: The manufacturer shall submit a certified test report for each LOT of material furnished to each project along with a statement certifying that the material

conforms to this specification and identifying the project number and manufacturer's LOT number.

932-1.5.4 Verification Samples: Provide verification samples in accordance with Section 6.

932-2 Structural Bearing Pads.

932-2.1 General: Provide bearing pads from producers who have a "Compliant" audit status with the AASHTO Product Evaluation & Audit Solutions for "Elastomeric Bridge Bearing Pads". Furnish elastomeric structural bearing pads as shown in the Contract Documents. Elastomeric bearing pads as defined herein shall include plain pads (elastomer only) and laminated bearing pads (elastomer with steel laminate inserts). Perform marking, sampling, testing and certification per this Section.

932-2.2 Materials and Sampling: Provide materials for plain and laminated bearing pads in accordance with this Table 932-5 and this Section. Provide steel that is melted and manufactured in the USA. Reclaimed material is not allowed in the finished product. External load bearing plates shall be finished or machined flat to within 0.01 inches. The bottom surfaces of external load plates (masonry plates) designed to rest on bearing pads shall not exceed an out of flatness value of 0.0625 inches. External load bearing plates (e.g., galvanized, or metalized) shall be protected from rust until all exposed surfaces can be welded. Any rust inhibitor shall be removed from all surfaces prior to welding.

Bearings with steel laminates shall be cast as a unit in a mold and bonded and vulcanized under heat and pressure. Bearings with steel laminates which are designed to act as a single unit with a given shape factor must be manufactured as a single unit. The mold shall have a standard shop practice mold finish. The internal steel laminates shall be blast cleaned to a cleanliness that conforms to SSPC-SP6 at the time of bonding. Plates shall be free of sharp edges and burrs and shall have a minimum edge cover of 0.25 inches. External load plates (sole plates) shall be hot bonded to the bearing during vulcanization.

Edges of the embedded steel laminates, including the laminate restraining devices and around holes and slots shall be covered with not less than 0.25 inches of elastomer or the minimum edge cover specified in the Plans. All exposed laminations or imperfections that result in less than the specified elastomer cover of any surface of the steel laminations shall be repaired by the manufacturer at the point of manufacture. The repair shall consist of sealing the imperfections flush on the finished pads with a bonded vulcanized patch material compatible with the elastomeric bearing pad. Repairs employing caulking type material or repairing the bearings in the field will not be permitted.

Table 932-5 Material Requirements for Structural Bearing Pads					
Product	Process	Material	Standard	Grade	Reportable Properties
Plain Pad	Molded Vulcanization or Extruded Vulcanization	Elastomer 100% virgin polychloroprene (neoprene)	AASHTO M 251 ARPM MO-1 F3-T.063 (Molded), F2-T (Extruded)	2, 3, 4, 5	Finish, Dimensions, Shear Strength, Tensile Strength, Shear Modulus, Elongation
Laminated Pad (Steel inserts)					
	Hot Rolled	10 gage Steel (Laminates)	ASTM A36	Any	Designation Grade
			ASTM A1011	Min. SS Gr. 36 Type 1	Yield, Tensile, Elongation, Killed

932-2.3 Dimensional Tolerances: Fabricate elastomeric bearings within the dimensional tolerances specified in AASHTO M 251, as modified below or as designated in the Plans. If any of the dimensions are outside the limits specified, the bearing pad shall be rejected.

Table 932-6 Dimensional Tolerances for Bearing Pads		
Measurement		Tolerance (inches)
Overall vertical dimensions	Design thickness ≤1.25 inches	-0, +0.125
	Design thickness >1.25 inches	-0, +0.25
Overall horizontal dimensions	measurements ≤36 inches	-0, +0.25
	measurements >36 inches	-0, +0.50
Thickness of individual layers of elastomer (laminated bearings only) at any point within the bearing		±0.125
Variation from a plane parallel to the theoretical surface (as determined by measurements at the edge of the bearings)	Top (slope relative to bottom)	≤0.005 radians
	Sides	0.25
Position of exposed connection members		±0.125
Edge cover of embedded laminates of connection members		-0, +0.125
Position and size of holes, slots, or inserts		±0.125

932-2.4 Marking: Each elastomeric bearing pad shall be permanently marked in indelible ink or flexible paint. The marking shall consist of the order number, LOT number, pad identification number, elastomer type, and shear modulus or hardness (when shear modulus is

not specified). Where possible, the marking shall be on a face of the bridge bearing pad that will be visible after erection of the structure.

932-2.5 Sampling: A sampling LOT shall consist of a maximum of 100 bearing pads of a single type of bearing (plain or steel laminated), of the same design, materials, thickness, and manufacturer, referred to here as "like pads", delivered to the project site or to an offsite storage facility within the State of Florida in reasonable proximity to the project site as determined by the Engineer. Organize stockpiled pads into groups of like pads by LOT so that they can be readily identified and sampled by the Engineer.

When the total number of like pads, as defined in 932-2, consists of a LOT of 10 or less, sampling is not required, and acceptance is by certification, as stated in 932-2.7.

For LOT sizes of like pads that exceed 10, two bearing pads per LOT will be selected by the Engineer, one for testing and one for verification in the event of a failing test result. LOT's will be sampled only after all like pads in the LOT are at the project site or in an offsite storage facility. Samples shall consist of complete pads as detailed in the Plans. Furnish additional complete bearing pads to replace those selected for testing. Bearing pads shall be available for sampling a minimum of three weeks prior to their installation. Submit the sample bearing pads to a Department approved independent laboratory for testing. Shipping and testing will be at the Contractor's expense.

932-2.6 Testing: Test bearing pads in accordance with Florida Method FM 5-598. Laminated bearings must meet a minimum compressive strength of 2,400 psi and non-laminated (plain) pads must meet a minimum compressive strength of 1,200 psi. The shear modulus of the elastomer shall be minimum 80 psi unless otherwise noted in the Contract Plans. If any properties are identified as noncompliant with the criteria specified, the bearing shall be rejected, and the verification sample tested. If the verification sample test results are also noncompliant, the LOT shall be rejected. A list of approved testing laboratories can be found on the Department's website. The URL for obtaining this information, if available, is: https://mac.fdot.gov/reports.

932-2.7 Certification: For Lot sizes ≤ 10, the Contractor shall submit to the Engineer a certification statement from the manufacturer that materials provided conform to the requirements of Section 6 and this Section, and the bearings in the LOT were manufactured in a reasonably continuous manner from the same batch of elastomer and cured under the same conditions. The certification shall identify the production facility, material, quantity, grade, and reportable properties as defined in Table 932-5 for each LOT.

For Lot sizes > 10, the Contractor shall submit to the Engineer a certification statement from the manufacturer that materials provided conform to the requirements of Section 6 and this Section, and the bearings in the LOT were manufactured in a reasonably continuous manner from the same batch of elastomer and cured under the same conditions. The certification shall identify the production facility. Additionally, the Contractor shall submit to the Engineer complete certified test results as required in FM5-598, from an independent laboratory.

932-3 Ancillary Bearing Pads.

932-3.1 General: Provide bearing pads from producers who have a "Compliant" audit status with the AASHTO Product Evaluation & Audit Solutions for "Elastomeric Bridge Bearing Pads". Structural bearing pads certified to meet 932-2 may be substituted for ancillary pads. Provide materials for ancillary plain pads in accordance with this section and Table 932-7. Perform testing and certification per this Section.

932-3.2 Plain Pads: Cutting shall not heat the material and shall produce a smooth finish with a maximum roughness average (Ra) of 6.3 µm (0.248 mils) measured in accordance with ASME B46.1. Plying pads of lesser thickness together shall not be permitted. External load plates (e.g., galvanized, or metalized), when used, shall be protected from rusting and shall be hot bonded by vulcanization during the primary molding process.

Table 932-7
Requirements for Ancillary Pad Material

Product	Manufacturing	Material	Standard	Grade	Properties
Plain Pad	Molded Vulcanization or Extruded Vulcanization	Elastomer 100% virgin polychloroprene (neoprene)	AASHTO M251 ARPM MO-1 F3-T.063 (Molded), F2-T (Extruded)	2, 3, 4, 5	Compressive Strength 1,200 PSI per FM 5-598

932-3.3 Testing and Certification: The Contractor shall provide a certification to the Engineer for all ancillary pads used outside of a railing application, confirming that each LOT of material meets the requirements of Section 6 and this Section and that the bearings were produced in a continuous manner from the same batch of elastomer and cured under the same conditions. The certification shall also the production facility, material, grade, and compressive strength for each LOT.

For bearing pads to be used under metal railings, submit a certification indicating the production facility and compliance with either of the following standards:

1. A certification stating that each LOT of material was reviewed, sampled, tested, and meets the requirements of Section 6 and this Section, and the bearings in the LOT were manufactured in a reasonably continuous manner from the same batch of elastomer and cured under the same conditions.

2. A certification stating that the pads were tested and meet ASTM D2000 M1 BC (suffix grade 1 - basic requirements, type B, class C).

932-4 Fiber Reinforced Polymer (FRP) Reinforcing Bars.

932-4.1 General: Obtain FRP reinforcing bars from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

Use only solid, round, thermoset basalt fiber reinforced polymer (BFRP), glass fiber reinforced polymer (GFRP) or carbon fiber reinforced polymer (CFRP) reinforcing bars. Single or multi-wire CFRP strands are permitted as spirals for reinforcing in concrete piling where specified in the Contract Documents. Bars shall be manufactured using pultrusion, variations of pultrusion, or other suitable processes noted in the producer's Quality Control Plan, subject to the approval of the State Materials Office (SMO). For BFRP and CFRP bars only vinyl ester or epoxy resin systems are permitted. For GFRP, use only bars manufactured using vinyl ester resin systems and glass fibers classified as E-CR or R that meet the requirements of ASTM D578.

932-4.2 Bar Sizes and Loads: The sizes and loads of FRP reinforcing bars shall meet the requirements in Table 932-8. The measured cross-sectional area, including any bond enhancing surface treatments, shall be determined according to Materials Manual Section 12.1 Volume II.

Table 932-8
Sizes and Tensile Loads of FRP Reinforcing Bars

Bar Size Designation	Nominal Bar Diameter (in)	Nominal Cross Sectional Area (in^2)	Measured Cross-Sectional Area (in^2)		Minimum Guaranteed Tensile Load (kips)			
			Minimum	Maximum	BFRP & GFRP Bars (Type 0)	BFRP & GFRP Bars (Type III)	CFRP (Type II) Single & 7-Wire Strands	CFRP (Type I) Bars
2.1-CFRP	0.21	0.028	0.026	0.042	-	-	7.1	-
2	0.250	0.049	0.046	0.085	6.1	7.4	-	10.3
2.8-CFRP	0.280	0.051	0.048	0.085	-	-	13.1	-
3	0.375	0.11	0.104	0.161	13.2	16.0	-	20.9
3.8-CFRP	0.380	0.09	0.087	0.134	-	-	23.7	-
4	0.500	0.20	0.185	0.263	21.6	27.9	-	33.3
5	0.625	0.31	0.288	0.388	29.1	40.8	-	49.1
6	0.750	0.44	0.415	0.539	40.9	57.3	-	70.7
6.3-CFRP	0.630	0.19	0.184	0.242	-	-	49.8	-
7	0.875	0.60	0.565	0.713	54.1	75.8	-	-
7.7-CFRP	0.770	0.29	0.274	0.355	-	-	74.8	-
8	1.000	0.79	0.738	0.913	66.8	94.9	-	-
9	1.128	1.00	0.934	1.159	82.0	115.0	-	-
10	1.270	1.27	1.154	1.473	98.2	138.7	-	-
11	1.410	1.56	1.500	1.700	105.8	160.0	-	-

932-4.3 Material Acceptance: Submit to the Engineer a certificate of analysis for each production LOT from the producer of the FRP reinforcing bars, confirming compliance with the requirements of this Section.

932-4.3.1 Sampling: The Engineer will select a minimum of six straight bars with minimum lengths of 7 feet each and a minimum of five bent bars or spiral bends/revolutions from each shipment, representing a random production LOT, per bar size of FRP reinforcing for testing in accordance with Table 932-9. Testing shall be conducted, at the Contractor's expense, by a Department approved independent laboratory. Each test shall be replicated a minimum of three times per sample. Submit the test results to the Engineer for review and approval prior to installation. Testing will not be required for bars to be used solely as reinforcement for sheet pile bulkheads, but LOT samples will still be selected and retained by the Engineer until final acceptance of the work.

Table 932-9 Testing Requirements for Project Material Acceptance of FRP Reinforcing Bars				
Property	Test Method	Requirement	Test Required for Straight Bar	Test Required for Bent Bar
Fiber Mass Fraction	ASTM D2584 or ASTM D3171	≥70%	Yes	Yes – bent portion[b]
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%	Yes	Yes – bent portion[b]
Glass Transition Temperature	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F	Yes	Yes – bent portion[b]
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy	Yes	Yes – bent portion[b]
Measured Cross-sectional Area	ASTM D7205	Within the range listed in Table 932-6	Yes	Yes – straight portion
Guaranteed Tensile Load[a]		≥ Value listed in Table 932-6	Yes	No
Tensile Modulus		≥6,500 ksi for BFRP and GFRP (Type 0) ≥8,500 ksi for BFRP and GFRP (Type III) ≥18,000 ksi for CFRP (Type I) Bars ≥22,400 ksi for CFRP (Type II) Strands	Yes	No

a – Guaranteed tensile load shall be equal to the average test result from all three LOTs minus three standard deviations.
b – Bent portion specimens shall be extracted from a central location within a 90° bend.

932-5 FRP Spirals for Concrete Piling.

FRP Spirals for reinforcing in concrete piling shall be CFRP conforming to the requirements of Section 933 or 932-4 for CFRP (Type II).

932-6 Polymer Slurries for Drilled Shafts.

932-6.1 General Requirements: Provide synthetic polymer slurry products to facilitate the construction of drilled shafts. Products must contain long chain-like hydrocarbon molecules which interact with each other, with the soil, and with the water to effectively increase the viscosity of the fluid and meet the requirements of the Materials Manual, Volume 2 Section 2.4. Products may be formulated in powder, granular or liquid forms. Products shall be capable of being mixed with potable water prior to introducing it to the drilled shaft excavation.

932-6.2 Product Acceptance: All materials shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and including documentation that meets the requirements of Table 932-10. A separate application must be submitted for each product type to be evaluated, showing that the product meets the applicable requirements.

Table 932-10
Documentation Requirements

Documentation	Requirements
Installation Instructions	Include mixing and disposal instructions and the Safety Data Sheet (SDS).
Product Photo	Displays the significant features of the product as required in this section. Displays location of Manufacturer name and model number.
Product Label Photo	Displays the Product Name
Technical Data Sheet	Uniquely identifies the product and includes product specifications, storage instructions, and recommended installation materials and equipment as applicable.
Test Reports	Submit test results and reports as required by Materials Manual, Vol 2 Section 2.4

SECTION 933
PRESTRESSING STRAND AND BAR

933-1 Strands for Prestressing.

933-1.1 Carbon Steel Strands for Prestressing: The carbon-steel strands for prestressing concrete members shall be Grade 270, low-relaxation seven wire strand conforming to the requirements of ASTM A416.

933-1.2 Stainless-Steel Strands for Prestressing: The stainless-steel strands for prestressing concrete members shall be a high strength stainless-steel (HSSS, Grade 240), low-relaxation seven wire strand conforming to the requirements of ASTM A1114.

933-1.3 Carbon-Fiber-Reinforced Polymer (CFRP) Strands for Prestressing: Obtain CFRP prestressing strands from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105. CFRP strand shall meet the requirements of this Section.

Table 933-1
Typical Sizes and Loads of CFRP Prestressing Strands and Bars

Type	Nominal Diameter (in)	Nominal Cross Sectional Area (in^2)	Nominal Ultimate Load (P_u) (kips)	Nominal Ultimate Tensile Stress (ksi)
Single Strand - 5.0mm Ø	0.20	0.025	9.1	364
7-strand - 7.9mm Ø	0.31	0.048	17.8	370
7-strand - 10.8mm Ø	0.43	0.090	33.1	367
Single Strand (Bar) - 9.5mm Ø	0.38	0.110	35.0	318
7-strand - 12.5mm Ø	0.49	0.117	43.3	370
Single Strand (Bar) - 12.7mm Ø	0.50	0.196	59.0	301
7-strand - 15.2mm Ø	0.60	0.179	66.2	369
7-strand - 17.2mm Ø	0.68	0.234	86.6	370
7-strand - 19.3mm Ø	0.76	0.289	106.9	370

933-1.4 Shipping and Storage: Protect carbon-steel, stainless-steel, and CFRP strands for prestressing against mechanical damage and contamination during shipping and storage.

933-2 Steel Bars for Prestressing.

The steel bars for prestressing concrete members shall conform to the requirements of ASTM A722, Type II.

933-3 Steel Parallel Wire Assemblies for Prestressing.

The wire assemblies for prestressing concrete members shall consist of parallel wires of the number and size shown in the Plans and shall conform to the requirements of ASTM A421.

933-4 Anchorages for Prestressing.

933-4.1 For Strands and Bars:

933-4.1.1 Steel Strands and Bars: Meet the requirements of Section 960.

933-4.1.2 Carbon Fiber Reinforced Polymer (CFRP) Strands: Meet the requirements of ACI 440.3R, B.10 – Test method for performance of anchorages of FRP bars.

933-4.2 For Steel Parallel Wire Assemblies: Anchorage for parallel wire assemblies may be provided by Type BA (Button Anchorages) cold-end deformation of the wires bearing against suitable anchorage plates, or by Type WA (Wedge-type Anchorages) without cold end deformations, of the sandwich-plate or conical type. The anchorage device shall be capable of developing at least 90% of the specified ultimate strength of the total number of wires anchored.

Conical type anchorages shall be embedded within the ends of the concrete members unless otherwise specified. Anchorages shall generally bear against embedded grids of reinforcing steel of approved type.

Alternate type anchorages will be considered if proposed by the Contractor. Any alternate anchorage will be required to develop the full specified ultimate strength for bars or at least 90% of the specified ultimate strength for parallel wire assemblies.

933-5 Required Tests for Prestressing Strand and Bar.

933-5.1 General: Tests shall be performed to determine the physical characteristics of prestressing reinforcement. For tests specified to be made by the producer, submit certified test results to the Engineer prior to use.

933-5.2 Strands:

933-5.2.1 Steel Strands: Acceptance of carbon-steel and stainless-steel prestressing strands shall be based on samples taken by the Department and the producer's certified mill analysis certifying that the test results meet the specification limits of ASTM, AASHTO, or FDOT as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT per shipment of strand.

Certified mill analyses for steel prestressing strand shall contain, for each heat number or production LOT, all test results required by ASTM A416 and ASTM A1114. Include the modulus of elasticity expressed in psi or the stress-strain curve with units identified.

The Engineer will select samples and certified mill analysis representing each shipment at a frequency of one sample per producer, per size of strand, per shipment.

933-5.2.2 Carbon-Fiber-Reinforced Polymer (CFRP) Strands:

933-5.2.2.1 Material Acceptance: Submit to the Engineer a certificate of analysis for each production LOT from the producer of the CFRP strand, confirming compliance with the requirements of this Section.

933-5.2.2.2 Sampling: The Engineer will select a minimum total of 42 feet from each shipment, representing a random production LOT, per size of CFRP strand for testing in accordance with Table 933-2. The minimum discrete sample length shall be 7 feet. Testing shall be conducted, at the Contractor's expense, by a Department approved independent laboratory. Each test shall be replicated a minimum of three times per sample. Submit the test results to the Engineer for review and approval prior to installation.

Table 933-2
Testing requirements for Project Material Acceptance of CFRP Prestressing Strand

Property	Test Method	Requirement
Fiber Mass Fraction	ASTM D2584 or	≥70%

Table 933-2 Testing requirements for Project Material Acceptance of CFRP Prestressing Strand		
Property	Test Method	Requirement
	ASTM D3171	
Short-Term Moisture Absorption	ASTM D570, Procedure 7.1; 24 hours immersion at 122°F	≤0.25%
Glass Transition Temperature	ASTM D7028 (DMA) or ASTM E1356 (DSC; T_m)/ASTM D3418 (DSC; T_{mg})	≥230°F ≥212°F
Degree of Cure	ASTM E2160	≥95% of Total polymerization enthalpy
Actual Cross Sectional Area	ASTM D7205	Within -5% to +10% of nominal values listed in Table 933-1
Ultimate Tensile Strength		≥ Value listed in Table 933-1
Tensile Modulus		≥18,000 ksi for Bar; ≥ 22,400 ksi for 7-strand & 5mm Ø

933-5.3 Steel Bars: Acceptance of steel prestressing bar shall be based on samples taken by the Department and the producer's certified mill analysis certifying that the test results meet specification limits of the ASTM or AASHTO as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT and size per shipment of bars. Certifications of steel prestressing bar shall contain, for each heat number or production LOT, all test results required by ASTM A722, and the modulus of elasticity expressed in psi or the stress-strain curve with units identified.

The Engineer will select samples and certified mill analysis representing each shipment at a frequency of one sample per heat or production LOT, per size of bar, per shipment.

933-5.4 Steel Wires: Acceptance of steel wires shall be based on the producer's certified mill analysis of test results meeting the specification limits of the ASTM or AASHTO as specifically designated. Prior to use, submit to the Engineer the producer's certified mill analysis for each heat or production LOT per shipment of wire. Certifications of steel prestressing wire shall contain, for each heat number or production LOT, all test results required by ASTM A421.

SECTION 934
NON-SHRINK GROUT

934-1 Scope.

This Section covers only prepackaged non-shrink cementitious grout for structural use.

934-2 Type Permitted.

Only non-metallic formulations of grouts are allowed. Gas producing, metal oxidizing and expansive aggregate grouts are not allowed.

934-3 Sampling and Testing Methods.

Perform concrete sampling and testing in accordance with the following methods:

Making and Curing Concrete Test Specimens in the Laboratory.....ASTM C192
Time of Setting Concrete Mixtures by Penetration Resistance .....ASTM C403
Determining Low-Levels of Chloride in Concrete and Raw Materials ..... FM 5-516
Compressive Strength of Hydraulic Cement Mortars.....ASTM C109
Flow of Grout for Preplaced Aggregate Concrete (Flow Cone Method).....ASTM C939
Measuring Changes in Height of Cylindrical Specimens from Hydraulic Cement Grout.....ASTM C1090
Expansion and Bleeding of Freshly Mixed Grout for Preplaced Aggregate Concrete in the Laboratory.....ASTM C940

934-4 Requirements.

When tested as provided in 934-3, the grout shall meet the following requirements:

Table 934-1	
Property	Test Value
Compressive strength	
one day	2,500 psi minimum
3 days	5,000 psi minimum
Time of set, final	8 hours maximum
Chloride Content	0.40lb/yd3 maximum
Hardened Height Change at 1, 3, 14, and 28 Days	0.0% to 0.3%
Hardened Height Change at 1, 3, and 14 Days	≤ Height Change @ 28 Days
Expansion	≤ 2.0% @ 3 Hours
Bleeding, Final	0.0% @ 3 Hours

934-5 Product Acceptance on the Project.

Non-shrink grout used shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

Acceptance will be made in accordance with the products listed on the APL.

934-6 Rejection.

Materials shall be rejected at the point of use if the materials are caked, lumpy, or show any signs of deterioration. Materials shall be rejected if the grout does not achieve the design fluidity or consistency when mixed according to the manufacturer's recommendations.

All broken or open packages shall be rejected.

934-7 Packaging.

Cementitious materials for grouts must be packaged in suitable moisture resistant containers and clearly labeled. Where applicable, manufacturers recommendations, limitations and cautions shall be clearly visible on each label.

SECTION 937
POST-INSTALLED ANCHOR SYSTEMS FOR STRUCTURAL APPLICATIONS IN CONCRETE ELEMENTS

937-1 General.

Post-installed anchor systems intended for structural applications in concrete elements consist of adhesive-bonded anchor systems.

937-2 Approved Product List (APL).

Manufacturers of post-installed anchor systems may apply for inclusion of individual products on the Department's Approved Product List (APL). The application shall be made in accordance with Section 6 and shall include certified test reports from an independent testing laboratory which shows the material system meets all the requirements of this Section.

937-3 Certification.

The Contractor shall provide the Engineer with certification from the manufacturer of the anchor system, confirming that the requirements of this Section are met. The certification shall conform to the requirements of Section 6. Each certification shall cover only one LOT of anchoring materials.

937-4 Adhesive Bonding Material Systems.

937-4.1 General: Adhesive bonding material systems for structural applications shall consist of pre-packaged, 2-part chemical components. The material systems shall be specifically intended for use in structural applications for bonding anchors and dowels to hardened concrete. Applications are limited to anchors and dowels installed in positions ranging from vertically downward to horizontal.

Do not use material from containers which are damaged or have been previously opened. Use only full packages of components. Combining of adhesive bonding components from bulk supplies is not permitted.

Material systems shall be pre-packaged to automatically proportion and mix the materials for use. Manual proportioning of the components will not be permitted.

937-4.2 Minimum Performance Requirements (FM 5-568): When tested in accordance with FM 5-568, the adhesive bonding material system, for general use, shall meet the following requirements:

Table 937-1
Uniform Bond Stress

	Type HV	Type HSHV
Confined Tension	2,290 psi	3,060 psi
Damp-Hole Installation	1,680 psi	1,830 psi
Elevated Temperature	2,290 psi	3,060 psi
Horizontal Orientation	2,060 psi	2,060 psi
Short Term Cure	1,710 psi	1,710 psi
Specified Bond Strength	1,080 psi	1,830 psi

Maximum Coefficient of Variation for Uniform Bond Stress: 20%.

Long Term Load (Creep):

1. The rate of displacement shall decrease during the 42 day application of load.

2. At 42 days, the total displacement due to creep (with load still applied) shall be less than 0.03 inches and during the last 14 days of the 42 day load duration, the total displacement due to creep shall be less than 0.003 inches.

3. After removal of the 42 day load, the uniform bond Stress from a subsequent Confined Tension Test shall not be less than 1,826 psi.

937-4.3 Product Identification (Fingerprint) Properties (FM 5-569): References for comparison including infrared absorption, density or average weight, gel time or setting time, and bond strength shall be determined in accordance with FM 5-569.

937-4.4 Packaging and Marking: The adhesive bonding material system shall be delivered to the project site in original unopened containers with the manufacturer's label identifying the product. Each package shall be clearly marked with the following information:

Manufacturer's name and address
Product Name
Date of Manufacture
Expiration Date
LOT Identification Number
Storage and Handling Requirements

Each package shall include the manufacturer's instructions for anchor and dowel installation. The instructions shall include the following information:

Diameters of drilled holes for applicable anchor and dowel sizes.

Cleaning procedure for drilled holes, including a description of permitted and prohibited equipment and techniques.

Allowable temperature ranges for storage, installation and curing.

Identification of acceptable mixing/dispensing nozzles.

Fabrication requirements for anchors and dowels.

Description of tools permitted or required for installation.

Method of identifying properly proportioned and mixed adhesive materials.

Time and temperature schedule for initial set and full-strength cure.

Special requirements for special installation conditions such as damp holes, or horizontal or near horizontal orientation of the anchor or dowel.

SECTION 938
DUCT FILLER FOR POST-TENSIONED STRUCTURES

938-1 Description.

This Section covers filler materials used to fill voided areas within ducts to protect post-tensioning steel. Grout applications are differentiated into three applications: horizontal, vertical and repair. There is no differentiation for flexible fillers.

938-2 Approved Product List.

Only post-tensioning grouts and flexible filler material listed on the Department's Approved Product List (APL) shall be used. Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6 and include certified test reports from an independent AASHTO R18 or ISO 9001 approved laboratory showing that the material meets all the requirements specified herein. A written certification from the manufacturer that the product meets the requirements of this Section must be submitted.

Any change of materials or material sources requires new testing and certification of the conformance of the grout with this Specification.

Grout products will be qualified by application (horizontal, vertical or repair).

938-3 General Requirements.

938-3.1 Grout: Grouts shall exhibit thixotropic properties and shall be prepackaged in clearly labeled moisture proof containers. The containers shall indicate application type, date of manufacture, LOT number and mixing instructions. The manufacturer's Quality Control Data Sheet for each lot number and shipment sent to the job site shall be provided to the Contractor and submitted to the Engineer.

938-3.2 Flexible Filler - Microcrystalline Wax: The flexible filler shall be a petroleum based microcrystalline wax delivered to the project site in clearly labeled prepackaged containers and stored in accordance with the manufacturer's recommendations as applicable for the particular project. The manufacturer's Quality Control Data Sheet for each shipment sent to the job site shall be provided to the Contractor and submitted to the Engineer.

938-4 Grout.

938-4.1 Mixing: The material shall be mixed in accordance with the manufacturer's recommendations except when additional water is indicated for particular tests.

938-4.2 Grout Physical Properties:

938-4.2.1 Gas Generation: The grout shall not contain aluminum or other components which produce hydrogen, carbon dioxide or oxygen gas.

938-4.2.2 Laboratory Testing: The grout shall meet or exceed the specified physical properties stated herein as determined by the following standard and modified ASTM and FM test methods conducted at normal laboratory temperature (65°F-90°F) and conditions. Prepare all laboratory test specimens using 110 percent of the maximum water allowed by the manufacturer unless otherwise noted in Table 938-1. Tests A, B, N, and O will be conducted by the Department.

Table 938-1			
Test ID	Property	Test Value	Test Method
A	Total Chloride Ions	Max. 1.0 lb/yd^3	FM 5-516 (1)
B	Total Sulfate Ions	Max. 30 ppm	FM 5-618 (1)
C	Gradation	99% passing the No. 50 95% passing the No. 100 90% passing the No. 170	ASTM C136(2)
D	Hardened Height Change @ 24 hours and 28 days	0.0% to + 0.2%	ASTM C1090
E	Expansion	≤ 2.0% for up to 3 hours	ASTM C940
F	Wet Density - Laboratory	Report maximum and minimum obtained test value lb/ft^3	ASTM C138
G	Wet Density - Field	Report maximum and minimum obtained test value lb/ft^3	ASTM C138 or ASTM D4380
H	Compressive Strength 28 day (Average of 3 cubes)	≥7,000 psi	ASTM C942
I	Initial Set of Grout	Min. 3 hours Max. 12 hours	ASTM C953
J	Time of Efflux immediately after mixing	Max. 12 seconds	ASTM C939(3)
K	Bleeding @ 3 hours	0.0 percent	ASTM C940(4)
L	Pressure Induced Bleeding	0.0 percent	ASTM C1741
M	Surface Resistivity@ 28 days	≥16 kOhms-cm	AASHTO T 358
N	Relative Viscosity, RV_f, determined from Dynamic Sheer Rheometry	< 1.15	FM 5-605
O	Inclined Tube Test		FM5-619
	Amount of Bleed	≤ 0.0%	
	Allowable Difference in Moisture	≤ 2.0%	
	Penetration at 500 psi	≤ 1 mm	

(1) Obtain test sample from upper vent of inclined tube test specimen after 7 days curing.

(2) Use ASTM C117 procedure to determine the percent passing after washing the sieve.

(3) The time of efflux is the time to fill a one liter container placed directly under the flow cone. Modify the ASTM C939 test by filling the cone to the top instead of to the standard level. Use the midrange of the water content indicated in the manufacturer's technical data sheet to produce the time of efflux.

(4) Use ASTM C940 to conform with the wick induced bleed test as modified by the Post-Tensioning Institute specification PTI M55.1-12.

938-4.3 Accelerated Corrosion Test Method (ACTM): Perform the ACTM as outlined in Appendix B of the Specification for Grouting of Post-Tensioning Structures published by the

Post-Tensioning Institute. Report the time to corrosion for both the grout being tested and the control sample using a 0.45 water-cement ratio neat grout.

A grout that shows a longer average time to corrosion in the ACTM than the control sample and the time to corrosion exceed 1,000 hours is considered satisfactory.

938-4.4 Variation in Testing for Specific Applications.

938-4.4.1 Horizontal Applications: Horizontal grout applications are defined as grouting of all superstructure tendons and transverse substructure tendons in caps, struts, etc. All physical requirements defined in 938-4.2 and 938-4.3 are applicable for grouts used in horizontal applications.

938-4.4.2 Vertical Applications: Vertical grout applications are defined as grouting of substructure column tendons. All physical requirements defined in 938-4.2 and 938-4.3 are applicable for grouts used in vertical applications.

938-4.5 Repair Applications: Repair applications are used to augment grouting operations which did not completely fill the duct or anchorage. For new construction, repairs may be made with the same filler approved for use in the tendon as long as the volume of the void is less 0.5 gal. In all other cases, use a non-sanded grout meeting the requirements of 938-4.2 and 938-4.3.

938-5 Flexible Filler - Microcrystalline Wax.

938-5.1 Storage and Preparation: Store and prepare wax in accordance with Section 462. Reject wax that shows any sign of segregation or decomposition prior to application even though it conforms to these Specifications. Use equipment designed for pumping the wax in a fluid state to fill the tendon ducts. Manufacturers shall include the recommended pumping temperature in the material technical data sheet.

938-5.2 Laboratory Testing: The wax shall meet the specified physical properties stated herein as determined by the following standard and modified ASTM and FM test methods conducted at normal laboratory temperature (65°F-78°F) and conditions. Prepare and test all laboratory test specimens as noted in Table 938-2.

Table 938-2

Property	Test Value	Test Method
Salt Fog – 168 hours@35°C	No corrosion	ASTM B117(1)
Chlorides	≤ 50 ppm (total)	ASTM D512(2)
Sulfate	≤ 100 ppm	ASTM D516(2)
Congealing Point	≥ 65°C	ASTM D938
Cone Penetration at 25°C	≤ 260 d-mm	ASTM D937
Bleeding at 40°C	≤ 0.5%	ASTM D6184
Resistance to Oxidation 100 hours at 100°C	≤ 0.03 MPa	ASTM D942
Kinematic Viscosity at 100°C	10 – 30mm^2/s	ASTM D445

(1) Test sample consists of a 4-inch x 6-inch steel panel blast cleaned to a NACE surface preparation SP5 or equivalent, with a 2 to 2.5 mil surface profile. The plate is covered with a layer of wax equivalent to 0.5 grams wax per square inch of panel.

(2) Prepare sample in accordance with NF M07-023, sections 6a through 6c or equivalent. Other analytical methods are acceptable as long as equivalency to the above methods has been established by the Department.

SECTION 942
PRECAST CONCRETE PIPE GASKETS

942-1 Round Rubber Gaskets for Pipe Joints.

Except where O-ring type gaskets are specified for special cases and for special type pipe, round rubber gaskets for use in concrete pipe joints shall meet the requirements of ASTM C443, with the additional requirements that the gasket used shall be of such cross sectional area and perimeter as to properly fit the space provided in the pipe joint in which it is to be used.

Prior to use, the gasket shall be stored in as cool a place as practicable.

942-2 Cold Adhesive Preformed Plastic Gaskets (For Sealing Elliptical Concrete Pipe Joints).

942-2.1 General: Cold adhesive preformed plastic gaskets shall be of a material, shape and size so as to effect a permanent water tight seal in joints of elliptical concrete pipe. A minimum of two pieces of gasket material shall be used in each joint.

The gasket material shall be protected by a 2-piece removable wrapper. To facilitate application, the 2-piece wrapper shall be so designed that one-half may be removed longitudinally without disturbing the other half.

The size of the gasket shall be in accordance with the manufacturer's recommendation for the particular joint in which it is to be used. However, the minimum size for each of the gaskets used in a joint shall be in accordance with the following:

Table 942-1

Pipe Size (Inches)	Nominal Gasket Size (Inches)	Minimum Cross-Section (In^2)
Up to 19 by 30	1-1/2	1.75
19 by 30 to 53 by 83	1-3/4	2.5
Over 53 by 83	2	3.25

The above minimum size requirements are based on a joint designed with a maximum taper of 10 degrees and an in-place annular space of approximately 1/4 inch.

942-2.2 Composition: The gasket sealing the joints shall be produced from blends of refined hydrocarbon resins and plasticizing compounds reinforced with inert mineral filler. The material shall contain no solvents and shall not produce irritating fumes or obnoxious odors. The gasket shall not depend on oxidizing, evaporation or chemical action for its adhesive or cohesive strength.

The chemical composition of the gasket material shall meet the following requirements:

Table 942-2		
	Minimum	Maximum
Bitumen (petroleum plastic content) (% by weight)	50	70
Ash-Inert Mineral Matter (% by weight)	30	50
Volatile Matter (@ 325ºF) (% by weight)		2.0

The gasket joint sealing compound when immersed for 30 days at ambient room temperature separately in 5% solution of caustic potash, a mixture of 5% hydrochloric acid, a 5% solution of sulfuric acid, and a saturated hydrogen sulfide solution shall show no visible deterioration.

The physical properties of the gasket joint sealing compound as shipped shall meet the following requirements:

Table 942-3		
	Minimum	Maximum
Specific Gravity @ 77ºF	1.2	1.35
Ductility @ 77ºF	50 mm	
Softening Point @ 77ºF	320ºF	
Penetration (0.1 mm) 77ºF @ (150 gms) five seconds	50	120

942-2.3 Certification: The manufacturer of the gasket material shall submit to the Engineer certified test results covering each shipment of material to each project.

942-3 Resilient Connectors for Sealing Precast Structures to Pipe Joints.

942-3.1 General: Resilient connectors shall meet the requirements of ASTM C923. The connectors shall also be compatible with the precast structure and pipe.

942-3.2 Approved Product List (APL): All resilient connectors shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

942-4 Profile Rubber Gaskets for Concrete Pipe Joints.

(a) Round Pipe: The gaskets shall meet the requirements of ASTM C443.

(b) Elliptical Pipe: The gaskets shall meet the requirements of ASTM C443.

Additionally, the gaskets used shall be of such cross sectional area and perimeter as to properly fit the space provided in the pipe joint in which it is to be used.

The gaskets shall be stored in as cool a place as practicable prior to use.

SECTION 943
CORRUGATED STEEL PIPE AND PIPE ARCH
(INCLUDING UNDERDRAIN)

943-1 General Requirements.

Corrugated steel pipe, including round culvert pipe, pipe arch and underdrain and coupling bands for each type shall conform to AASHTO M 36 and shall include plant certification from AASHTO Product Evaluation & Audit Solutions. Except for underdrain, corrugated steel pipe including pipe arch shall be fabricated with helical corrugations with a minimum of two annular corrugations formed on each end of each pipe to accommodate a coupling band. Annular fabrication is not permitted unless specifically called for in the Plans or Specifications. Provide, as part of the shipping ticket, the actual mean inside diameter and total measured lengths of each LOT of pipe shipped to the project. Include the minimum and maximum inside diameters used to calculate the actual mean inside diameter.

943-2 Round Culvert Pipe.

For round culvert pipe used as sidedrain, unless shown otherwise in the Plans, the minimum thickness of the metal (including galvanizing - AASHTO M 218, or aluminum coating - AASHTO M 274), shall be as specified below. Alternatively, if no future maintenance concerns exist, the Contractor may propose the pipe gage based on the Department's Drainage Manual and Culvert Service Life Estimator for approval by the Engineer.

Table 943-1 Thickness of Metal for Sidedrain Pipe		
Nominal Diameter (Inches)	Metal Sheet Gauge No.	Mean Thickness Metal (Inches)
6	18	0.0516
8	16	0.0635
10	16	0.0635
12	16	0.0635
15	16	0.0635
18	16	0.0635
21	16	0.0635
24	16	0.0635
30	14	0.0785
36	14	0.0785
42	12	0.1084
48	12	0.1084
54	12	0.1084
60	10	0.1382
66	10	0.1382
72	10	0.1382
78	8	0.1681
84	8	0.1681
90	8	0.1681
96 and over	8	0.1681

Table 943-2 Permissible Variation in Thickness of Metal for Pipe and Connecting Bands		
Metal Sheet Gauge No	Mean Thickness of Metal (Inches)	Permissible Variation (Inches)
18	0.0516	0.007
16	0.0635	0.007
14	0.0785	0.008
12	0.1084	0.009
10	0.1382	0.009
8	0.1681	0.009

943-3 Pipe Arch.

For corrugated metal pipe arch, in addition to the requirements shown in AASHTO M 36, thickness of the metal shall be as shown for the equivalent size round pipe in Tables 943-1 and 943-2, above, and the fabrication of the pipe arch sections shall be such as to insure a substantially flat invert.

943-4 Alternate Connecting Bands.

In addition to the connecting bands as specified in AASHTO M 36, alternate types of connecting bands are specified in 430-8.1.3, for use with the types of installations as shown.

943-5 Bituminous Coating and Paved Invert.

When bituminous coating is specified, the pipe, or pipe arch, shall be coated in accordance with the requirements of AASHTO M 190, for Type A (Fully Bituminous Coated).

When bituminous coated and paved invert are specified the pipe or pipe arch shall be coated and paved in accordance with AASHTO M 190, for Type C (Fully Bituminous Coated and Paved). The temperature of the asphalt at the time of coating and the duration of the pipe submerged time shall be optimized such that excess coating does not adhere to the pipe.

943-6 Paved Interior.

When bituminous coated and paved interior are called for, the coating and paving shall meet the requirements specified above for bituminous and paved invert (Type C), with the following additions and exceptions:

1. The smooth pavement formed by the asphalt cement shall extend over the entire interior of the pipe.
2. The exterior coating and the interior paving shall be applied.
3. No markings will be required on the outside of the pipe to designate the center line of the top of the pipe.
4. Lifting lugs shall be attached to the pipe, and shall be suitably placed to facilitate moving the pipe without damage to the exterior or interior bituminous material.

943-7 Basis of Acceptance of Bituminous Coating and Paving.

The acceptance of the bituminous coating, paved invert, and paved interior will be based on the raw materials manufacturer's certification of compliance with AASHTO M 190.

943-8 Underdrain Pipe.

Corrugated metal pipe for underdrain shall conform to the requirements of AASHTO M 36 except that Class IV pipe, as specified in Section 18.1.1.4 therein, shall not be used.

SECTION 944
STRUCTURAL PLATE STEEL PIPE AND PIPE ARCH

944-1 Description.

This Section covers the materials for corrugated galvanized steel structural plate pipe and pipe arch, including the necessary bolts and nuts for connecting plates and for assembling the pipe or pipe arch at the point of destination when so specified. The sizes of the pipe or pipe arch shall be as shown in the Plans.

944-2 Materials.

Structural plate pipe and pipe arch shall be of galvanized steel, mill certified to the requirements of AASHTO M 167, with the additional requirement that the minimum thickness of the plates shall be as shown in the Plans. Hardware must comply with the requirements of AASHTO M 167.

944-3 Tolerance in Span and Height.

A tolerance of plus or minus 4% will be allowed in the specified span and height of pipe arches. A tolerance of minus 2 inches to plus 4 inches will be allowed in the specified diameter of round pipe.

944-4 Bituminous Coating.

When bituminous coating is specified, all plates shall be fully coated on both sides with asphalt cement. The bituminous coating shall conform to the requirements of AASHTO M 190, for Type A.

944-5 Mill Analysis and Certification.

Provide a Mill Test Report for all metal components. Report the average and minimum zinc coating mass for the pipe. When bituminous coatings are used, provide a statement of compliance for bituminous coatings meeting AASHTO M 190, Type A.

944-6 Assembly Diagrams.

Diagrams for assembling shall be furnished unless the pipe or pipe arch is furnished completely assembled.

944-7 Fabrication.

The fabrication of the pipe and pipe arch shall comply with the applicable requirements of Section 23, of the AASHTO LRFD Bridge Construction Specifications. Unless otherwise specified, the pipe and pipe arch shall be of full section for the entire length.

944-8 Assembly.

When purchase contracts stipulate that the pipe be assembled, the dealer shall furnish the pipe and pipe arch completely assembled at the point of destination, or at the site, as specified, and in lengths as specified.

944-9 Direct Purchases by the Department.

When the Department purchases the pipe or pipe arch direct from the dealer, the quantity to be paid for shall be the number of feet of pipe and of pipe arch, as ordered, provided that

sufficient materials meeting the requirements of these specifications shall be furnished to construct the pipe and pipe arch of the length and sizes shown.

The quantity shall be the net length as ordered, with no allowance for length in excess thereof.

The price per foot for direct purchases shall be full compensation for furnishing the complete materials for the pipe or pipe arch, including all bolts and nuts required for connecting the plates. When assembling of the pipe or pipe arch is specified, such price shall also include all labor, equipment, tools and incidentals required for completely assembling the pipe or pipe arch.

SECTION 945
ALUMINUM PIPE, INCLUDING UNDERDRAIN, PIPE ARCH AND STRUCTURAL PLATE PIPE AND PIPE ARCH

945-1 General Requirements.

Aluminum-alloy culvert pipe and underdrains shall meet the requirements of AASHTO M 196 and shall include plant certification from AASHTO Product Evaluation & Audit Solutions and compliance with the additional provisions contained herein. Except for underdrain, corrugated aluminum pipe including pipe arch shall be fabricated with helical corrugations with a minimum of two annular corrugations formed into each end of each pipe to accommodate a coupling band. Annular fabrication is not permitted unless specifically called for in the Plans or specifications. Provide, as part of the shipping ticket, the actual mean inside diameter and total measured lengths of each lot of pipe shipped to the project. Include the minimum and maximum inside diameters used to calculate the actual mean inside diameter.

For sidedrains, unless shown otherwise in the Plans the minimum thickness of the metal shall be as specified below. Alternatively, if no future maintenance concerns exist, the Contractor may propose the pipe gage based on the Department's Drainage Manual and Culvert Service Life Estimator for approval by the Engineer.

Table 945-1
Thickness of Metal for Sidedrain Pipe

Nominal Diameter or Equivalent (inches)	Sheet Gauge No.	Mean Thickness of Metal (inches)
6	18	0.048
8	16	0.060
10	16	0.060
12	16	0.060
15	16	0.060
18	16	0.060
21	16	0.060
24	16	0.060
30	14	0.075
36	14	0.075
42	12	0.105
48	12	0.105
54	12	0.105
60	10	0.135
66	10	0.135
72 and over	8	0.164

Where bituminous coated aluminum pipe is specified the bituminous coating shall meet the requirements as specified for corrugated steel pipe in 943-5. Bituminous coated and paved aluminum pipe shall meet the additional requirements specified in 943-6 and 943-7, as applicable.

Class IV pipe shall not be used.

945-2 Aluminum Alloy Structural Plate Pipe, Pipe Arch and Arches.

945-2.1 General Requirements: Aluminum alloy structural plate pipe, pipe arch, and arches shall conform to AASHTO M 219, with the exceptions and additions specified herein. The nominal thickness of the plate shall be as shown in the Plans.

945-2.2 Bolts and Nuts: In lieu of shaped bolts and nuts, standard type bolts and nuts, with special shaped washers, may be used. For aluminum bolts and nuts the material shall conform to the chemical requirements shown in Table I of ASTM B211, for Alloy 6061. Nuts shall be lubricated at the factory, with a suitable wax compound. The bolts may be sampled and tested before erection or may be accepted on the basis of the manufacturer's certification.

For steel bolts and nuts, the material shall meet the requirements of either ASTM A307 or ASTM F3125, Grade A325, as appropriate, and shall be hot double-dipped galvanized. Aluminized steel bolts, or other equally suitable devices for connecting the plates, may be used if approved by the Engineer.

945-2.3 Certification of Tests: Submit to the Engineer, prior to installation, a certified mill analysis and certification verifying that the aluminum parts and components are of the alloys specified and comply with the requirements of this Section.

945-2.4 Direct Purchases by the Department: The provisions of 944-9 shall also apply to Departmental purchases of aluminum alloy structural plate pipe, pipe arches and arches.

945-2.5 Pipe Markings: In lieu of the coined markings required by AASHTO M 196, Section 14, information may be ink stamped on the pipe at the time of manufacture. A QC label with the pipe fabricator's identity, the date of corrugating or forming into pipe, and the date of final QC inspection shall be applied to the inside walls of pipe using indelible ink. The pipe markings must be clearly legible upon arrival at the jobsite and at the time of installation. Pipe with illegible or incomplete markings may be rejected.

SECTION 946
CAST IRON PIPE

946-1 Cast Iron Culvert Pipe.

Cast iron culvert pipe of diameter 12 inches and over shall conform with the requirements of AASHTO M 64, including the requirements for the coating as specified in Article 7.1. Cast iron culvert pipe smaller than 12 inches in diameter shall meet ANSI A21.51, and the joints shall meet ANSI A21.11.

Unless a particular type or class of pipe is designated in the plans the Contractor may furnish any class included in the above specifications. Only one class or type shall be furnished for any one Contract. The pipe shall be smooth bore pipe.

946-2 Cast Iron Soil Pipe.

Cast iron soil pipe, for roof drains or for other purposes where such pipe is designated, shall meet the requirements of either of the following:

1. ASTM A74, for service-type pipe.
2. The building code of the municipality or other governmental authority having jurisdiction within the area of the installation.

SECTION 948
OPTIONAL DRAINAGE PRODUCTS AND REPAIR SYSTEMS

948-1 Polyvinyl-Chloride (PVC) Pipe, or Acrylonitrile-Butadiene-Styrene (ABS) Plastics Pipe.

948-1.1 For Bridge Drains: PVC pipe shall conform to the requirements of ASTM D1785, for Type I, Grade 1, Schedule 80 PVC pipe with a minimum polymer cell classification of 12454 per ASTM D1784 and a minimum of 1.5% by weight of titanium dioxide for UV protection.

948-1.2 Pressure Pipe: Pressure pipe for direct burial under pavement shall conform to the requirements of ASTM D1785, for Type I, Grade I, Schedule 40, for sizes up to and including 2-1/2 inches, and Schedule 80 for sizes up to 4 inches. Pressure pipe 4 inches in diameter and larger shall conform to the requirements of AWWA C900-75, DR18, and ASTM D1785, Type I, Grade I or other types as may be specifically called for in the Plans or Special Provisions.

948-1.3 Pipe Marking: All PVC pipe shall be marked as required by Article 8 of ASTM D1785, and acceptance of the pipe may be based on this data.

948-1.4 Nonpressure Pipe: PVC pipe and ABS pipe intended for direct-burial or concrete encasement, shall meet the following requirements:

1. PVC Pipe: ASTM D3034, SDR-35, or ASTM F949, profile wall without perforations.
2. ABS Pipe: ASTM D2680.

The manufacturer of the PVC or ABS pipe shall submit to the Engineer the mill analysis covering chemical and physical test results.

948-1.5 Underdrain: PVC pipe for use as underdrain shall conform to the requirements of ASTM F758 or ASTM F949. Also, PVC underdrain manufactured from PVC pipe meeting ASTM D3034, perforated in accordance with the perforation requirements given in AASHTO M 36 or AASHTO M 196 will be permitted.

948-1.6 Edgedrain: PVC pipe for use as edgedrain shall conform to the requirements of ASTM F758, ASTM F949 or ASTM D3034 pipe shall be perforated in accordance with the perforation requirements given in AASHTO M 36 or AASHTO M 196. Additional perforations will be required as indicated in Standard Plans, Index 446-001 for pipes designated under ASTM F758 and ASTM D3034. PVC pipe intended for direct burial in asphalt shall meet the following requirements:

1. ASTM D3034, SDR-35, or ASTM F949
2. NEMA TC-2 (pipe material and compounds) and NEMA TC-3 (pipe fittings) for PVC (90ºC electrical conduit pipe) NEMA ECP-40 and NEMA ECP-80. Underwriter Laboratory Specifications referenced under NEMA specifications for electrical conductivity are not required.
3. Pipe shall withstand asphalt placement temperatures specified without permanent deformation.
4. Perforations shall be in accordance with AASHTO M 36 or AASHTO M 196.

948-1.7 PVC Pipe (12 Inches to 48 Inches): PVC pipe for side drain, cross drain, storm drain and other specified applications shall conform to AASHTO M 278 for smooth wall PVC pipe or ASTM F949 and AASHTO M 304 for PVC ribbed pipe with plant certification from

AASHTO Product Evaluation & Audit Solutions. Resin shall contain a minimum of 1.5% by weight of titanium dioxide for UV protection. Post-consumer and post-industrial recycled resins are not allowed. Mitered end sections are not to be constructed of PVC.

PVC pipe shall be installed within two years from the date of manufacture.

Obtain pipe from a production facility that is listed on the Department's Production Facility Listing. Producers seeking inclusion shall meet the requirements of Section 105.

948-1.7.1 Material Acceptance: Prior to use, submit to the Engineer a material certification from the manufacturer confirming that the requirements of this Section are met. The certification shall conform to the requirements of Section 6.

Project sampling shall be performed in accordance with 430-9.

948-2 Corrugated Polyethylene Tubing and Pipe.

948-2.1 General: For underdrain, corrugated polyethylene tubing and fittings shall meet the requirements of AASHTO M 252. For edgedrain, corrugated polyethylene tubing and fittings shall meet the requirements of AASHTO M 252, except as modified in 948-2.2. For storm drain side drain, french drain and cross drain corrugated polyethylene pipe shall meet the requirements of AASHTO M 294 and 948-2.3.

The tubing or pipe shall not be left exposed to sunlight for periods exceeding the manufacturer's recommendation.

948-2.2 Edgedrain (4 Inches to 10 Inches): The requirements for edgedrain as specified in AASHTO M 252 are modified as follows:

1. Coiling of tubing 6 inches in diameter or greater is not permitted. Tubing shall have a minimum pipe stiffness of 46 psi at 5% deflection.

948-2.3 Corrugated High Density Polyethylene (HDPE) Pipe (12 Inches to 60 Inches):

948-2.3.1 General: Class I (50-year design service life) corrugated HDPE pipe used for side drain, storm and cross drain or french drain shall meet the requirements of AASHTO M 294(V) with plant certification from the AASHTO Product Evaluation & Audit Solutions. Corrugations shall be annular. Pipe resin shall conform to ASTM D3350 with a minimum cell classification 435400C and between 2% to 4% carbon black. Post-consumer and post-industrial recycled resins are not allowed. Mitered end sections are not to be constructed of polyethylene.

Obtain pipe from a production facility that is listed on the Department's Production Facility Listing. Producers seeking inclusion shall meet the requirements of Section 105.

948-2.3.2 Additional Requirements for Class II (100-Year Design Service Life), Type S HDPE Pipe: Class II HDPE pipe shall meet the requirements in Table 948-1 in addition to those in 948-2.3. Perforations will not be allowed. Manufacturers may only use ground Class II HDPE pipe for reworked plastic.

948-2.3.2.1 Requirements for Use in Structures with Resilient Connectors: Use gasketed corrugated pipe sleeve adapters to completely seal to and cover the pipe corrugations. Corrugated pipe sleeve adapters shall be an elongated bell with a smooth outer wall, manufactured at a minimum of 12-inches in length and inserted over the double gasketed corrugations. The sleeve adapters shall be manufactured from polypropylene resin compounds in accordance with ASTM F2881. Upon installation, the connection with the resilient connector shall meet the requirements of ASTM F2510.

Table 948-1 Stress Crack Resistance of Pipes			
Pipe Location	Test Method	Test Conditions	Requirement
Pipe Liner	FM 5-572, Procedure A	10% Igepal solution at 122°F and 600 psi applied stress, 5 replicates	Average failure time of the pipe liner shall be ≥18.0 hours, no single value shall be less than 13.0 hours.
Pipe Corrugation[1], (molded plaque)	ASTM F2136	10% Igepal solution at 122°F and 600 psi applied stress, 5 replicates	Average failure time shall be ≥24.0 hours, no single value shall be less than 17.0 hours.
Junction	FM 5-572, Procedure B and FM 5-573	Full Test[2][3] Test at 3 temperature/stress combinations: 176°F at 650 psi 176°F at 450 psi 158°F at 650 psi; 5 replicates at each test condition	Determine failure time at 500 psi at 73.4°F ≥ 100 years (95% lower confidence) using 15 failure time values[4] The tests for each condition can be terminated at duration equal to or greater than the following criteria: 110.0 hr at 176°F 650 psi 430.0 hr at 176°F 450 psi 500.0 hr at 158°F 650 psi
		Single Test[5]: Test temperature 176°F and applied stress of 650 psi.; 5 replicates	The average failure time must be equal to or greater than 110.0 hr
Longitudinal Profiles[6]	FM 5-572, Procedure C, and FM 5-573	Full Test[2][3]: Test at 3 temperature/stress combinations: 176°F at 650 psi 176°F at 450 psi 158°F at 650 psi; 5 replicates at each test condition	Determine failure time at 500psi at 73.4°F ≥ 100 years (95% lower confidence) using 15 failure time values[4]. The tests for each condition can be terminated at duration equal to or greater than the following criteria: 110.0 hr at 176°F 650 psi 430.0 hr at 176°F 450 psi 500.0 hr at 158°F 650 psi
		Single Test[5]: Test temperature 176°F and applied stress of 650 psi.; 5 replicates	The average failure time must be equal to or greater than 110.0 hr (no value shall be less than 55.0 hours)

Table 948-1 Stress Crack Resistance of Pipes			
Oxidation Resistance of Pipes			
Pipe Location	Test Method	Test Conditions	Requirement
Liner and/or Crown(7)	OIT Test (ASTM D3895)	2 replicates (to determine initial OIT value) on the as manufactured (not incubated) pipe.	25.0 minutes, minimum
Liner and/or Crown(7)	Incubation test FM 5-574 and OIT test (ASTM D3895)	Three samples for incubation of 265 days at 176°F(8) and applied stress of 250 psi. One OIT test per each sample	Average of 3.0 minutes(9) (no values shall be less than 2.0 minutes)
Liner and/or Crown(7)	MI test (ASTM D1238 at 190ºC/2.16Kg)	2 replicates on the as manufactured (not incubated) pipe.	< 0.4 g/10 minutes
Liner and/or Crown(7)	Incubation test FM 5-574 and MI test (ASTM D1238 at 190°C/2.16Kg)	2 replicates on the three aged sampled after incubation of 265 days at 176°F(8) and applied stress of 250 psi	MI Retained Value(9)(10) shall be greater than 80% and less than 120%.

Note: FM = Florida Method of Test.
(1) Required only when the resin used in the corrugation is different than that of the liner.
(2) A higher test temperature (194°F) may be used if supporting test data acceptable to the State Materials Engineer is submitted and approved in writing.
(3) Full test shall be performed on alternative pipe diameter of pipe based on wall profile design, raw material cell classification, and manufacturing process. Full test must be performed on maximum and minimum pipe diameters within a manufacturing process.
(4) Computer program to predict the 100 year SCR with 95% lower confidence can be obtained from FDOT.
(5) Single test for the junction and longitudinal profile may be used on alternating pipe sizes within a manufacturing process. Single point tests may not be used on maximum and minimum pipe sizes within a manufacturing process except by approval of the Engineer. Single point tests may be used for quality assurance testing purposes.
(6) Longitudinal profiles include vent holes and molded lines.
(7) OIT and MI tests on the crown are required when resin used in the corrugation is different than that of the liner.
(8) The incubation temperature and duration can also be 196 days at 185°F.
(9) The tests for incubated and "as-manufactured" pipe samples shall be performed by the same lab, same operator, the same testing device, and in the same day.
(10) The MI retained value is determined using the average MI value of incubated sample divided by the average MI value of as-manufactured pipe sample.

948-2.3.3 Material Acceptance: Meet the requirements of 948-1.7.1.

948-2.3.4 Laboratory Accreditation: Manufacturers seeking evaluation of a product in accordance with Departmental procedures must submit test reports conducted by a laboratory qualified by the Geosynthetic Accreditation Institute-Laboratory Accreditation Program (GAI-LAP) or qualified by ISO 17025 accreditation agency using personnel with actual experience running the test methods for Class II HDPE pipe. Submit the test reports to the State Materials Office.

948-2.4 Steel Reinforced Polyethylene Ribbed Pipe:

948-2.4.1 General: Steel reinforced polyethylene ribbed pipe used for side drain, storm and cross drain, or french drain shall meet the requirements of AASHTO M 335 with plant certification from the AASHTO Product Evaluation & Audit Solutions and the testing

requirements for stress crack and oxidation resistance in Table 948-1. Pipe resin shall conform to ASTM D3350 with a minimum cell classification 435400C and between 2% to 4% carbon black. Post-consumer and post-industrial recycled resins are not allowed. Mitered end sections are not to be constructed of steel reinforced polyethylene ribbed pipe.

Obtain pipe from a production facility that is listed on the Department's Production Facility Listing. Producers seeking inclusion shall meet the requirements of Section 105.

948-2.4.2 Material Acceptance: Meet the requirements of 948-1.7.1.

948-2.4.3 Laboratory Accreditation: Meet the requirements of 948-2.3.4 except use personnel with actual experience running the test methods for steel reinforced polyethylene ribbed pipe.

948-2.5 Steel Reinforced Polyethylene Corrugated Pipe:

948-2.5.1 General: Class I (50-year design service life) steel reinforced polyethylene corrugated pipe used for side drain, storm and cross drain must meet the requirements of AASHTO MP 42 with plant certification from the AASHTO Product Evaluation & Audit Solutions, provided such certification for this category of pipe is available. Pipe resin must conform to ASTM D3350 with a minimum cell classification of 334452C or E and between 2% to 4% carbon black. Thermosetting polyurethane materials used for pipe joints must be polyester-based and meet the requirements of Table 948-2. Post-consumer and post-industrial recycled resins are not allowed. Perforations are not allowed. Mitered end sections are not to be constructed of steel reinforced polyethylene corrugated pipe.

Obtain pipe from a production facility that is listed on the Department's Production Facility Listing. Producers seeking inclusion to the listing shall meet the requirements of Section 105.

Table 948-2
Polyurethane Component Requirements

Test Methods	Test Conditions	Requirement
ASTM D2240 Durometer Hardness 1-inch Thick Specimens	Initial	≥60
	After 6 Months Exposure to Each Condition*	No more than 10% reduction from measured initial value
ASTM D695 Compressive Properties 0.1 inch per minute Load Rate	Initial	≥200 psi
	After 6 Months Exposure to Each Condition*	No more than 10% reduction from measured initial value
ASTM D1623 Yield Tensile Strength Type B Specimens 0.1 inch per minute Load Rate	Initial	≥300 psi
	After 6 Months Exposure to Each Condition*	No more than 30% reduction from measured initial value

*Exposure Conditions:

Solution pH	Resistivity (Ohm-cm), Minimum	Chloride Content (ppm), Maximum	Temperatures (°C)
5.5	1,000	300	60, 80, 90
7	1,000	300	60, 80, 90
12	1,000	300	60, 80, 90

948-2.5.2 Project Material Acceptance: Prior to use, submit to the Engineer a material certification from the manufacturer confirming that the requirements of this Section are met. The certification shall conform to the requirements of Section 6.

948-2.5.3 Laboratory Accreditation: Manufacturers seeking evaluation of a product in accordance with Departmental procedures must submit test reports conducted by a laboratory qualified by the Geosynthetic Accreditation Institute-Laboratory Accreditation Program (GAI-LAP) or qualified by ISO 17025 accreditation agency using personnel with actual experience performing the test methods for steel reinforced polyethylene pipe. Submit the test reports to the State Materials Office.

948-3 Fiberglass Reinforced Polymer Pipe.

948-3.1 For Bridge Drains: Fiberglass pipe shall conform to the requirements of ASTM D3262, ASTM D2996 or ASTM D2310, for Type I, Grade 2, Class E, using polyvinyl ester as the only resin. The minimum hoop stress designation shall be A. The resin shall contain UV stabilizers or a two-part 100% solids polyurethane coating.

948-4 Ductile Iron Pipe.

948-4.1 For Bridge Drains: Ductile iron pipe shall conform to the requirements of AWWA C151.

948-5 Hot Dip Galvanized Steel Pipe.

948-5.1 For Bridge Drains: Hot dip galvanized steel pipe shall conform to the requirements of ASTM A53.

948-6 Flexible Transition Couplings and Pipe.

948-6.1 For Bridge Drains: Flexible transition couplers and pipe shall conform to the requirements of ASTM C1173.

948-7 Profile Wall Polypropylene (PP) Pipe (12 Inches to 60 Inches).

948-7.1 Class I PP: Class I (50-year design service life) PP pipe used for side drain, cross drain, storm drain, and french drain shall meet the requirements of AASHTO M 330 with plant certification from the AASHTO Product Evaluation & Audit Solutions. Corrugations shall be annular. Polypropylene compound shall conform to the requirements of ASTM F2881. Post-consumer and post-industrial recycled resins are not allowed. Mitered end sections are not to be constructed of polypropylene.

Obtain pipe from a production facility that is listed on the Department's Production Facility Listing. Producers seeking inclusion shall meet the requirements of Section 105.

948-7.2 Additional Requirements for Class II (100-Year Design Service Life) PP Pipe: Meet the requirements in Table 948-3 in addition to those in 948-7.1. Manufacturers may only use ground Class II PP for reworked plastic.

948-7.2.1 Requirements for Use in Structures with Resilient Connectors: For PP pipe 24 inches and less in diameter, use gasketed corrugated pipe sleeve adapters to completely seal to and cover the pipe corrugations. Corrugated pipe sleeve adapters shall be an elongated bell with a smooth outer wall, manufactured at a minimum of 12-inches in length and inserted over the double gasketed corrugations. The sleeve adapters shall be manufactured from polypropylene resin compounds in accordance with ASTM F2881. Upon installation, the connection with the resilient connector shall meet the requirements of ASTM F2510.

For PP pipe 30 inches or greater in diameter, use at least one section of AASHTO M330-Class II Type D (triple wall) pipe at the pipe to structure connection.

Table 948-3 Stress Crack Resistance			
Pipe Location	Test Method	Test Conditions	Requirement
Pipe Liner	FM 5-572, Procedure A	10% Igepal solution at 50°C and 600 psi applied stress, 5 replicates	Average failure time of the pipe liner shall be ≥100 hours, no single value shall be less than 71 hours.(1)
Oxidation Resistance			
Pipe Location	Test Method	Test Conditions	Requirement
Pipe Liner and/or Crown(2)	OIT Test (ASTM D3895)	2 replicates (to determine initial OIT value) on the as manufactured (not incubated) pipe.	25.0 minutes, minimum
Pipe Liner and/or Crown(2)	Incubation test FM 5-574 and OIT test (ASTM D3895)	Three samples for incubation of 264 days at 85°C(3). One OIT test per each sample	Average of 3.0 minutes(4) (no values shall be less than 2.0 minutes)
Pipe Liner and/or Crown(2)	MI test (ASTM D1238 at 230°C/2.16Kg)	2 replicates on the as manufactured (not incubated) pipe.	< 1.5 g/10 minutes
Pipe Liner and/or Crown(2)	Incubation test FM 5-574 and MI test (ASTM D1238 at 230°C/2.16Kg)	2 replicates on the three aged sampled after incubation of 264 days at 85°C(3)	MI Retained Value(4)(5)(6) shall be greater than 80% and less than 120%.

Note: FM = Florida Method of Test.

(1) If due to sample size this test cannot be completed on the liner then testing shall be conducted on a molded plaque sample. Samples can be removed if test time exceeds 100 hours without failure.
(2) OIT and MI tests on the crown are required when resin used in the corrugation is different than that of the liner.
(3) The incubation temperature and duration can also be 192 days at 90°C or 140 days at 95°C.
(4) The tests for incubated and "as-manufactured" pipe samples shall be performed by the same lab, same operator, the same testing device, and in the same day.
(5) Within each replicate set of tests, the discrepancy range shall be within 9%. If an out-of-range discrepancy occurs, repeat the two MI tests on the same pipe sample. If insufficient material is available, a repeat of one test is acceptable.
(6) The MI retained value is determined using the average MI value of incubated sample divided by the average MI value of as-manufactured pipe sample.

948-7.3 Material Acceptance: Meet the requirements of 948-1.7.1.

948-7.4 Laboratory Accreditation: Meet the requirements of 948-2.3.4 except use personnel with actual experience running the test methods for profile wall polypropylene pipe.

948-8 Filter Fabric Sock for Use with Underdrain.

For Type I underdrain specified in Standard Plans, Index 440-001, filter sock shall be an approved strong rough porous, polyester or other approved knitted fabric which completely

covers and is secured to the perforated plastic tubing underdrain in such a way as to prevent infiltration of trench backfill material.

The knitted fabric sock shall be a continuous one-piece material that fits over the tubing like a sleeve. It shall be knitted of continuous 150 denier yarn and shall be free from any chemical treatment or coating that might significantly reduce porosity and permeability.

The knitted fabric sock shall comply with the following physical properties:

Table 948-4		
Weight, applied (oz/sq. yd.)	3.5 min	ASTM D3887
Grab tensile strength (lbs.)	50 min.*	ASTM D5034
Equivalent opening size (EOS No.)	25 min.**	Corps of Engineers CW-02215-77
Burst strength (psi)	100 min.**	ASTM D3887
*Tested wet. **Manufacturer's certification to meet test requirement.		

The knitted fabric sock shall be applied to the tubing in the shop so as to maintain a uniform applied weight. The tubing with knitted fabric sock shall be delivered to the job site in such manner as to facilitate handling and incorporation into the work without damage. The knitted fabric sock shall be stored in UV resistant bags until just prior to installation. Torn or punctured knitted fabric sock shall not be used.

948-9 Repair Systems for Rehabilitation of Pipe and Other Drainage Structures.

948-9.1 General: Repair systems shall have at least the minimum stiffness required for the intended application in accordance with the AASHTO LRFD Bridge Design Specifications.

948-9.2 Folded Liner: Folded liner shall be manufactured in an out of form state, usually collapsed circumferentially, and folded on the long axis. After installation in a host structure, the liner is formed by means of heat and pressure to fit the host structure. When installed, folded liner shall extend from one structure to the next in one continuous length with no intermediate joints.

948-9.2.1 Polyethylene: Folded polyethylene liner shall meet the requirements of ASTM 2718 or ASTM F714 with a minimum cell classification of 335420 and between 2% to 4% carbon black.

948-9.2.2 PVC: Folded PVC liner shall meet the requirements of ASTM F1504 (meet all the requirements for cell classification 12334 or 13223) or ASTM F1871 (meet all the requirements for cell classification 12111).

948-9.2.3 Cured-In-Place: Folded resin impregnated flexible tubing shall meet the requirements of ASTM F1216 and ASTM D5813.

948-9.3 Prefabricated (Slip) Pipe Liner: When used in slip lining applications, prefabricated liner shall be round, flexible or semi-rigid liner, manufactured in lengths that may be joined in a manhole or access pit before insertion in a host pipe.

948-9.3.1 Polyethylene:

1. Solid wall polyethylene pipe liner shall meet the requirements of ASTM F714 or AASHTO M 326 and shall have a minimum cell classification of 345464 and between 2% to 4% carbon black.

2. Profile wall polyethylene pipe liner shall meet the requirements of AASHTO M 294 and shall have a minimum cell classification of 435400 and between 2% to 4% carbon black.

3. Steel reinforced polyethylene pipe liner shall meet the requirements of AASHTO MP 20-13, ASTM F2562 or ASTM F2435 and shall have a minimum cell classification of 334452 and between 2% to 4% carbon black.

948-9.3.2 PVC:

1. Solid wall PVC pipe liner shall meet the requirements of ASTM D2729 and shall have a minimum cell classification of 12454.

2. Profile wall PVC pipe liner shall meet the requirements of ASTM F794, ASTM F949, or AASHTO M 304 and shall have a minimum cell classification of 12454.

948-9-3.3 Fiberglass: Prefabricated fiberglass pipe liner shall meet the requirements of ASTM D3262.

948-9.4 Spiral-Wound Liner: Spiral-wound liner shall consist of coils of profile strips or one piece profile strips that are wound directly into a host pipe helically

948-9.4.1 Polyethylene: Polyethylene spiral-wound liner shall meet the requirements of ASTM F1697 or ASTM F1735, except the resin shall conform to ASTM D3350 with a minimum cell classification of 335420 and between 2% to 4% carbon black.

948-9.4.2 PVC: PVC spiral-wound liner shall meet the requirements of ASTM F1697 or ASTM F1735 and shall have a minimum cell classification of 12454.

948-9.4.3 Steel Reinforced: Steel reinforced spiral-wound liner shall meet the requirements of ASTM F1697 or ASTM F1735, except the resin shall conform to ASTM D3350 with a minimum cell classification of 335420 and between 2% to 4% carbon black. The steel reinforcement shall be fully encapsulated to prevent exposure to corrosive elements.

948-9.5 Segmental Panel Liner: Segmental panel liner consists of custom fit flat or curved panels that are formed to the inside wall of a host structure.

948-9.5.1 Polyethylene: Polyethylene segmental panel liner shall meet the requirements of ASTM F1735, except the resin shall conform to ASTM D3350 with a minimum cell classification of 345464 and between 2% to 4% carbon black.

948-9.5.2 PVC: PVC segmental panel liner shall meet the requirements of ASTM F1735 and shall have a minimum cell classification of 12454.

948-9.6 Point Repair Systems: Point repair systems may be used to repair and rehabilitate an isolated portion of an existing structure and may consist of any materials covered by this specification. Materials that shall be used as primary components of point repair apparatus are:

1. Stainless steel, which shall meet the requirements of AASHTO M 167M, ASTM A167, or ASTM A240

2. Aluminum, which shall meet the requirements of AASHTO M 196

3. Rubber, which shall meet the requirements of ASTM C923.

948-9.7 Spray Applied Repair Systems: Spray applied repair systems consist of liquid, slurry, foam or gel that is sprayed over the interior surface or injected into specific locations of an existing structure or pipe to rehabilitate it, with or without fiber reinforcement. Spray applied repair system installers shall submit to the Department proof of experience for on-site supervision and previously completed contracts including the following:

1. Project name and location

2. Names of contracting parties

3. Owner’s names

4. A brief description of the work

5. Dates of completion of spray applied liner work

Materials that may be used for spray applied lining are:

1. Hydrophilic urethane-based foams or gels which shall meet the requirements of ASTM F2414.

2. Epoxy resins and unsaturated styrene-based resins which shall meet the resin material requirements of ASTM F1216.

3. Cementitious materials, as recommended by the manufacturer, including: annular backfill, low density cellular concrete, shotcrete, gunite, centrifugally cast, and pre-packaged grout.

4. High-strength, low-porosity geopolymer materials, as recommended by the manufacturer.

SECTION 949
MISCELLANEOUS COMPONENTS FOR MANHOLES, INLETS AND OTHER STRUCTURES

949-1 Clay Brick and Shale Brick.

This brick shall meet the requirements of ASTM C62, Grade MW or ASTM C32, Grade MM.

949-2 Concrete Brick.

Concrete brick shall meet the requirements of ASTM C55.

949-3 Concrete Masonry Units.

Concrete masonry units for use in manholes, inlets and similar structures shall meet the requirements of ASTM C139.

949-4 Precast Grade Adjustment Rings.

Precast grade adjustment rings shall meet the requirements of ASTM C478.

949-5 Composite Rubber Adjustment Rings.

Composite rubber adjustment rings shall meet the following minimum material requirements:

Table 949-1

Physical Properties	Requirements	Test Method
Density, lb./ft3	65 ± 5%	ASTM D3574-05, Test A
Durometer Hardness, Molded Surfaces, Shore A	75A ± 10	ASTM D2240-05
Tensile Strength, psi	145 (minimum)	ASTM D412-06
Ultimate Elongation %	15 ± 5	ASTM D412-06
Compression Deformation %, Initial	6 ± 2	ASTM D575-91(01)
Compression Deformation %, Final	6 ± 2	ASTM D575-91(01)
Coefficient of Thermal Expansion	10x10-5 ± 5x10-5	ASTM E831-05

949-6 Acceptance.

Submit to the Engineer a certification from the manufacturer stating that the bricks, concrete masonry units, precast grade adjustment rings or composite rubber adjustment rings meet the requirements of this Section. Acceptance of materials will be in accordance with Section 6.

SECTION 951
INSPECTION OF TIMBER PRODUCTS

951-1 Control of Quality.

All timber products manufactured for incorporation into the work shall be produced by a producer/treater approved through one of the following third-party audit programs:

1. Southern Pine Inspection Bureau (SPIB)
2. Timber Products (TPI)

Products produced under this QC Plan will not relieve the Contractor of his responsibility for unsuitable materials or workmanship, which might become apparent at the job site, nor of the necessity of his replacing any material which might be determined upon subsequent inspection to be unsuitable.

951-2 Certification.

Each order/shipment to the job site must be delivered with a ‘quality mark’ stamped by the third party quality assurance company. For material not eligible to be marked, the timber producer must produce a ‘certificate of inspection’ by the third party quality assurance company. Each order/shipment to the job site must be accompanied with a notarized certification indicating compliance to the appropriate specifications. The certification shall include: the project/order number, timber species, charge numbers, and assay retention results.

SECTION 952
STRUCTURAL TIMBER

952-1 General Specifications for All Structural Timber.

This Section specifies the requirements for pine timber to be used as structural members in the Department's work, including untreated timber as well as timber to be treated. All such timber shall be manufactured and graded in accordance with the current edition of the Standard Grading Rules for Southern Pine Timber, of the Southern Pine Inspection Bureau. The timber shall meet the requirements of No. 1 grade or as otherwise specified in the Plans.

952-2 Timber for Other Specific Uses.

952-2.1 Specification Grade: For timber to be used for columns, sills, wheelguards, bulkhead, sheeting, bracing, fender wales, or any other purpose for which the grade is not specified otherwise, the specification grade shall be as follows:

Table 952-1

Nominal Thickness	Nominal Width	Grade
1 to 1.5 inches	2 inches and wider	No. 1 Boards
2 to 4 inches	2 inches and wider	No. 1 Dimension
5 inches and larger	5 inches and larger	No. 2 Timbers

952-2.2 Permissible Knot Sizes for Fender Wales: For timber used as fender wales, the maximum permissible size of knot (at any point on any face) shall be as follows:

For nominal width of face of 10 - 3-3/4 inches.
For nominal width of face of 12 - 4-1/2 inches.

952-3 Untreated Pine Timber - Specific Requirement for Heartwood.

In addition to meeting all of the requirements of 952-1 and 952-2, pine timber which is to be used as untreated timber will be required to show at least 85% of heartwood on any girth.

SECTION 953
TIMBER PILING
(INCLUDING TIMBER SHEET PILING)

953-1 General.

Piles shall be of timber which will stand the driving for which they are intended. They shall be sound and solid. Piling cut from southern pine shall contain at least 30% of summer wood.

Cypress piles used for purposes other than as foundation piling shall have, at the butt, a diameter of red or black heart of at least 12 inches.

Douglas fir used for timber piling shall be Pacific Coast Douglas Fir.

Piles shall be cut above the ground swell, shall have a form taper, and shall not vary more than plus or minus 6 inches from the specified length.

Specific requirements for timber sheet piles are contained in 953-6.

953-2 Diameter of Butt and Tip.

For round piles the minimum butt diameter shall be 12 inches, measured at a section 3 feet from the end.

For piles up to 50 feet in length, the minimum tip diameter shall be 8 inches. For lengths in excess of 50 feet, a graduated reduction in tip diameter at the rate of 1 inch for each 10 feet of length in excess of 50 feet will be permitted. This reduction will correspond to 7 inch tips for 60 foot piles and 6 inch tips for 70 foot pile; at which length these allowable reductions shall cease. As an exception to the above, when so shown in the Plans, 7 inch diameter tips on timber piles less than 60 feet in length will be accepted. No piles shall have tips less than 6 inches in diameter. The maximum diameter at the cut-offs shall be 20 inches.

953-3 Straightness Requirements.

A straight line drawn from the center of the butt to the center of the tip shall not, at any point, fall further away from the center of the pile than a distance equal to 1% of the length of the pile.

The surface of the pile shall not contain kinks greater than 1 inch in 5 feet, as measured by a straightedge.

953-4 Peeling and Trimming.

The pile shall be peeled soon after cutting. In the operation of removing the bark from the pile, not more than three annual rings of the solid wood shall be removed. All knots shall be trimmed close to the body of the pile.

953-5 Permissible Knots and Other Defects.

The diameter of sound knots shall not exceed one-third of the diameter of the pile at the point where the knot occurs.

In these Specifications, a sound knot shall be defined as a knot which is solid across its face, is as hard as the surrounding wood and shows no indication of decay. It may vary in color from red to black and may contain a pith hole not more than 1/4 inch in diameter.

An unsound knot may or may not be as hard as the surrounding wood, but contains decay, and will be allowed only in accordance with the restrictions in ASTM D25.

Any defect, or combination of defects, which would be more injurious than the maximum allowable knot will not be acceptable.

Turpentine cuts will be allowed on all timber piles provided that no single cut shall exceed one-half of the circumference of the pile, and that the length of the cut shall not be more than 15% of the length of the pile. Piles to be used as outside piles in timber bents shall not have more than one turpentine cut.

953-6 Timber Sheet Piles.

Unless a particular species of timber is called for in the Plans, timber sheet piles may consist of any species which will satisfactorily stand driving. They shall be sawn square and shall be free from worm holes, loose knots, wind shakes, decayed or unsound portions, and other defects which might impair the strength or tightness

The piles shall be of the dimensions shown in the Plans and shall be treated in accordance with Section 955.

SECTION 954
TIMBER FENCE POSTS AND BRACES

954-1 Types of Timber and Treating Requirements.

Timber fence posts and braces shall be of southern yellow pine and shall be treated in accordance with Section 955.

Prior to the treatment, all knots on the posts shall be trimmed close to the body of the post.

954-2 Requirements for Cutting.

Round or sawn posts will be permitted but all posts on a single project shall be the same. Sawn post shall comply with AASHTO M 168, have a minimum Fb of 1,350 psi, be grade-stamped by an inspection agency accredited by the American Lumber Standards Committee (ALSC), and shall meet the requirements of 954-6. Round posts shall be cut from sound and solid trees and shall contain no unsound knots. The butt shall be cut at a sufficient distance above the ground swell of the tree that there will be no abrupt change in cross-section of the post.

The butts shall be sawn square. The post tops shall be sawn neatly and at right angles to the vertical axis of the post.

954-3 Knots, etc.

Sound knots will be permitted provided the diameter of the knot does not exceed one-third of the diameter of the piece at the point where it occurs.

Peck (in cypress posts) shall be limited as provided for knots; the area of permissible peck not exceeding the area occupied by permissible knots, and a combination of peck and knots not exceeding the aggregate of knots allowed.

The posts shall be free from decayed wood, rot, and red heart, and of ring shake or season checks which penetrate at any point more than one fourth the diameter of the piece, or are greater than 1/4 inch wide.

954-4 Peeling.

All posts shall be peeled for their full length, and all inner and outer bark removed, except that isolated strips of inner bark which do not exceed 1/2 inch in width or 3 inches in length will be permitted.

954-5 Straightness.

The straightness of the post shall be such that for any 8 foot post (or for any 8 feet of length, for longer posts) a straight line from the center of the tip to the center of the butt (or from center of the cross sections at the extremes of the 8 foot lengths) shall not fall outside the center of the mid-section of the 8 foot length by more than 2 inches.

954-6 Dimensions.

954-6.1 Minimum Lengths Allowable:

Line posts - 8 feet.

Corner and pull posts - 8 feet, 6 inches.

Braces - As required by the Plans.

(A tolerance of minus 1 inch to plus 2 inches will be allowed in the lengths shown for the posts.)

954-6.2 Minimum Allowable Cross Section:

Round line posts - 4 inch diameter.

Round braces, corner and pull posts - 5 inch diameter.

Square line posts - 4 inches by 4 inches.

Square braces, corner and pull posts - 5 inches by 5 inches.

The minimum diameters specified for round posts are applicable before preservative treatment. When the treated post is inspected at the job site a tolerance of 3/8 inch under such diameters will be allowed, to compensate for shrinkage resulting from treatment and storage.

SECTION 955
TIMBER TREATMENT
(INCLUDING TREATING MATERIALS)

955-1 General.

The work specified in this Section is the treating of structural timber, timber piling and timber posts, bracing and railing. The method of treatment and determination of assay results for all such timber materials shall be in accordance with American Wood Protection Association (AWPA) Use Category System (UCS) - U1, with the exceptions and additions as specified herein. All timber products manufactured for incorporation into the work shall be produced by a producer/treater approved through one of the following third-party audit programs:

1. Southern Pine Inspection Bureau (SPIB)
2. Timber Products (TPI)

955-2 Preservative.

955-2.1 Guardrail Post, Fence Post, Bracing and Railing on Pedestrian Bridges, Buildings, and Rest Areas in Above Ground, Ground Contact, Fresh Water Immersion Applications (Pedestrian Use): Provide guardrail post, fence post, bracing and railing in accordance with Table 955-1. Approved producers should provide a certification showing the timber species, treatment, and assay results with every shipment.

Table 955-1				
Product	Type / Species	Category	Treatment	Assay Results
Guardrail Posts, Fence Post, Bracing, & Railing	Southern Yellow Pine	UC4A	Micronized Copper Azole (MCA)	≥ 2.4 kg/m^3 or ≥ 0.15 pcf
			Copper Azole Type C (CA-C)	
			Copper Azole Type B (CA-B)	≥ 3.3 kg/m^3 or ≥ 0.21 pcf
			Alkaline Copper Quat Type A, (ACQ-A)	≥ 6.4 kg/m^3 or ≥ 0.40 pcf
			Alkaline Copper Quat Type B, (ACQ-B)	
			Alkaline Copper Quat Type C, (ACQ-C)	
			Alkaline Copper Quat Type D, (ACQ-D)	

955-2.2 Guardrail Posts, Fence Posts, Bracing and Sheet Piling in Above Ground, Ground Contact or Fresh Water Immersion Applications (Non-Pedestrian Use): Provide guardrail post, fence post, bracing and sheet piling in accordance with Table 955-2. Approved producers should provide a certification showing the timber species, treatment, and assay results with every shipment.

Table 955-2				
Product	Type / Species	Category	Treatment	Assay Results
Guardrail Posts, Fence Post, Bracing	Southern Yellow Pine	UC4A	MCA	≥ 2.4 kg/m^3 or ≥ 0.15 pcf
			CA-C	
			CA-B	≥ 3.3 kg/m^3 or ≥ 0.21 pcf
			Ammoniacal Copper Zinc Arsenate (ACZA)	≥ 6.4 kg/m^3 or ≥ 0.40 pcf
			Chromated Copper Arsenate Type C (CCA)	
			ACQ-A ACQ-B ACQ-C ACQ-D	
Piling	Cypress		None	N/A
	Southern Yellow Pine	UC4B UC4C	ACZA	≥ 9.6 kg/m^3 or ≥ 0.60 pcf
			CCA	≥ 9.6 kg/m^3 or ≥ 0.60 pcf
	Pacific Coast Douglas Fir		ACZA	≥ 9.6 kg/m^3 or ≥ 0.60 pcf

955-2.3 Guardrail Post, Fence Post, Bracing and Sheet Piling for Salt and Brackish Water Applications (Non-Pedestrian): Provide guardrail post, fence post, bracing and sheet piling in accordance with this section and Table 955-3. Approved producers should provide a certification showing the timber species, treatment, and assay results with every shipment.

Table 955-3				
Product	Type / Species	Category	Treatment	Assay Results
Guardrail Posts, Fence Post, Bracing	Southern Yellow Pine	UC4C	CCA	≥ 9.6 kg/m^3 or ≥ 0.60 pcf
Piling	Cypress	UC5C	None	N/A
	Southern Yellow Pine		CCA	Zone 1 (Outer): ≥ 40 kg/m^3 or ≥ 2.50 pcf Zone 2 (Inner): ≥ 24 kg/m^3 or ≥ 1.50 pcf
	Pacific Coast Douglas Fir		ACZA	40 kg/m^3 or ≥ 2.50 pcf

955-2.4 Structural Timber: Provide structural timber in accordance with this section and Table 955-4. Approved producers should provide a certification showing the treatment and assay results with every shipment.

Table 955-4				
Product	Type / Species	Category	Treatment	Assay Results
Boards, Dimensional, Timber	Southern Yellow Pine	UC4B	CCA	≥ 9.6 kg/m^3 or ≥ 0.60 pcf

955-3 Handling Waterborne Preservative Treated Piling.

In handling of piles that have been treated with chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA), cable slings shall be used. Mechanical grabbers or pointed tools shall not be permitted. Rough or careless handing shall be avoided at all times.

955-4 Identification of Treating Plants for Round Piling.

The treating plant shall brand, or place a distinctive permanent mark, on each round pile, approximately 6 feet from the butt end, such that the plant responsible for the treatment can be readily determined at any time during the service life of the piling.

SECTION 960
POST-TENSIONING COMPONENTS

960-1 Description.

This Section covers all post-tensioning (PT) systems and components remaining in a completed structure, including temporary erection PT left in-place and permanent PT for design capacity.

The submittal for approval of PT systems must use materials and components meeting the requirements of this Section and Section 462. Submit PT system shop drawings to the Engineer for review and acceptance in accordance with Section 5. The PT system shop drawings must include component drawings, system drawings, and test reports. The acceptance of a PT system for use on the project is based on the exact major components, as defined in 960-2, that were used in system testing and that are shown on the approved PT system shop drawings.

960-1.1 Material References: Meet the requirements of this Section and the following:

Epoxy Compounds*	Section 926
Bar (post-tensioning)	Section 933
Duct Filler for Post Tensioned Structures*	Section 938
Reinforcing Steel (mild)	Section 415
Parallel Wire (post-tensioning)	Section 933
Strand (post-tensioning)	Section 933

*Use products listed on the Department's Approved Product List (APL).

960-2 Component Standards.

All PT system components must be materials compatible with the filler material and installation process used to encapsulate the tendons. The component materials must not chemically degrade during the service life of the structure. The service life of the structure is 75-years unless specified otherwise in the Contract Documents.

The following are major components and must be marked with the manufacturer's name, trademark, model number, and size corresponding to catalog designation: anchorages, bearing plates, trumpets, caps, duct couplers, connections, "O"-rings, heat shrink tubing, duct, and local zone reinforcement. Any of these items that cannot be marked must be contained in packaging or appropriately tagged with the necessary information.

The following are examples of common off-the-shelf accessories and need not be stamped: bolts, washers, inlets, outlets, drains, ports, valves, plugs, nipples, hose adapters, and grease.

Substitution, modification, or deletion of any major component of the PT system, excluding local zone reinforcement, after system testing and approval by the Engineer is not permitted.

Provide only PT systems utilizing tendons completely encapsulated in grout or flexible filler filled anchorages and ducts. Do not use systems transferring prestress force by bonding prestress steel strand directly to concrete. Embedded anchorages for bars are permitted. Strand or strand-tendon couplers are not permitted.

960-2.1 Anchorage Assembly:

1. Construct anchorages from ferrous metal.

2. Anchorages shall develop at least 95% of PT steel actual ultimate strength when tested in an unbonded state, without exceeding anticipated anchor set.

3. Average concrete bearing stress shall be in compliance with AASHTO LRFD Bridge Design Specifications and AASHTO LRFD Bridge Construction Specifications.

4. Test anchorages with typical local zone reinforcement shown in system drawings.

5. Test anchorages in accordance with AASHTO LRFD Bridge Construction Specifications, or the European Assessment Document Post-Tensioning Kits for Prestressing of Structures (EAD 160004-00-0301, September 2016 Edition) with the exception that the design concrete strength used in the testing will be 6,500 psi. For anchorages that will be used for tendons with flexible filler, test anchorages in accordance with EAD 160004-00-0301 Section C.3 Resistance to Fatigue.

6. Anchorages with grout or flexible filler outlets shall be suitable for inspection from either top or front of anchorage. Anchorages may be fabricated to facilitate both inspection locations or may be two separate anchorages of the same type, each providing singular inspection entry locations.

7. Geometry of grout and flexible filler outlets must facilitate access for borescope inspection directly behind wedge plate using a straight 3/8 inch diameter drill bit.

8. Ferrous metal components of an anchorage that are to be embedded in concrete shall be galvanized in accordance with Section 962. Other anchorage assembly components, including wedges, wedge plates, and local zone reinforcement need not be galvanized.

9. All anchorages shall have a permanent vented anchorage cap bolted to the anchorage.

960-2.1.1 Trumpets:

1. Trumpets associated with anchorages shall be constructed from ferrous metal galvanized per ASTM A123, high-density polyethylene or polypropylene.

2. For connections between the trumpet and corrugated duct, the trumpet thickness at transition location shall be the thickness of the corrugated duct or greater.

3. For connections between the trumpet and smooth plastic duct, the trumpet thickness at the transition location shall be the minimum thickness provided in Table 960-1 or greater.

Table 960-1
Trumpet Thickness at the Transition Location

System Size	Minimum Trumpet Thickness at the Transition Location
4-Strand	0.08 inch
7-Strand	0.08 inch
12-Strand	0.10 inch
19-Strand	0.12 inch
27-Strand	0.14 inch
31-Strand	0.16 inch

960-2.1.2 Wedges and Wedge Plates:

1. Wedge plate shall be ferrous metal.

2. Wedge plates must have centering lugs or shoulders to facilitate alignment with bearing plate.

3. For longitudinal tendons greater than four strands, design system with separate wedge plate and anchorage plate.

960-2.2 Filler Containment Assembly:

960-2.2.1 Duct and Pipe:

1. Use plastic duct, steel pipe, or a combination of plastic duct and steel pipe in accordance with this Section.

2. Ducts shall be manufactured by a seamless fabrication method. Fabricate all duct splices to prevent kinks during all phases of construction.

3. Do not alter the natural duct color that results from UV protected polymer.

4. Corrugated ferrous metal ducts are prohibited.

960-2.2.1.1 Corrugated Plastic Duct:

1. PT systems with duct injected with grout shall use corrugated polypropylene material except where steel pipe is required.

2. Furnish ducts with minimum wall thickness as follows:

Table 960-2
Corrugated Plastic Duct Minimum Wall Thicknesses

Duct Shape	Duct Diameter*	Duct Minimum Wall Thickness
Flat	Any Size	0.08 inch
Round	0.9 inch	0.08 inch
Round	2.375 inch	0.08 inch
Round	3.0 inch	0.10 inch
Round	3.35 inch	0.10 inch
Round	4.0 inch	0.12 inch
Round	4.5 inch	0.14 inch
Round	5.125 inch	0.16 inch
Round	5.71 inch	0.16 inch

*The diameter is the nominal inner diameter of the duct.

960-2.2.1.2 Smooth Plastic Duct:

1. PT systems with duct injected with flexible filler shall use smooth high-density polyethylene duct.

2. Duct shall have a maximum dimension ratio (DR) of 17 as established by either ASTM D3035 or ASTM F714, as appropriate for manufacturing process used.

3. Duct shall have a minimum pressure rating of 125 psi.

960-2.2.1.3 Steel Pipe: Steel pipes shall be ASTM A53, Type E, Grade B, Schedule 40 and galvanized in accordance with Section 962.

960-2.2.1.4 Minimum Internal Diameter:

1. For prestressing bars, duct shall have a minimum internal diameter of 1/2 inches larger than bar outside diameter, measured across deformations.

2. For prestressing bars with couplers, duct shall have a minimum internal diameter of 1/2 inches larger than largest dimension of the largest enclosed element.

3. For multi-strand tendons, ducts must have a minimum cross-sectional area 2-1/2 times PT steel cross-sectional area.

960-2.2.1.5 Connections, Fittings, and Tolerance:

1. Devices or methods for all duct connections (e.g., splices, joints, couplers, connection to anchorages), shall produce smooth interior alignment with no lips or kinks.

2. Use of tape, caulking, epoxy, or other sealants is not permitted to join or repair duct, to make connections, or for any other purpose.

3. Use a reducer when adjacent sections of duct are directly connected to each other and the outside diameters vary more than plus or minus 0.08 inch.

4. Provide all connections that are external to the concrete with a minimum pressure rating of 150 psi.

5. Use heat shrink sleeves and circular sleeve couplers made from high-density polyethylene or polypropylene material, or duct couplers made from high-density polyethylene or polypropylene material with O-rings or seals to make connections between sections of corrugated plastic duct or between corrugated plastic duct and trumpets.

6. Use heat shrink sleeves and circular sleeve couplers made from high-density polyethylene or polypropylene material to make connections between corrugated plastic duct and steel pipe.

7. Use heat shrink sleeves with or without circular sleeve couplers made from high-density polyethylene or polypropylene material to make connections between corrugated or smooth plastic duct and anchorages with integral trumpets that are internal to the concrete.

8. Use heat welding techniques, electrofusion duct couplers, or elastomer sleeves and stainless steel band clamps to make connections between sections of smooth plastic duct.

9. Use elastomer sleeves and stainless steel band clamps to make connections between smooth plastic duct and steel pipe.

10. Use welding or elastomer sleeves and stainless steel band clamps to make connections between sections of steel pipe that are external to the concrete.

11. Use welding, elastomer sleeves and stainless steel band clamps or heat shrink sleeves and circular sleeve couplers made from high-density polyethylene or polypropylene material to make connections between steel pipe and trumpets that are internal to the concrete.

12. Use elastomer sleeves with a minimum wall thickness of 3/8 inch and reinforced with a minimum of four ply polyester reinforcement. Use a 3/8-inch-wide stainless steel power seated band and clamps on each end of the elastomer sleeves to secure the sleeves to plastic ducts or steel pipes. Seat the bands with a 120-pound-force prior to clamping them in place.

960-2.2.1.6 Segmental Duct Couplers:

1. Include segmental duct couplers for permanent internal PT systems at joints between match cast precast segments.

2. Use “O”- rings or compression seals between adjoining sections of segmental duct couplers.

3. Plastic duct couplers shall be high-density polyethylene or polypropylene material.

4. Metallic components shall be stainless steel per 960-2.4.3.

5. Segmental duct couplers shall mount perpendicular to the bulkhead at segment joints and provide for duct alignment.

6. Segmental duct couplers shall be able to receive duct at an angle of 6 degree deviation from perpendicular.

7. Segmental duct couplers must be able to accommodate angular deviation of duct without tendon strands touching duct or coupler on either side of segment joint.

8. Ducts for prestressing, used exclusively for temporary erection PT that is to be removed from structure, are not required to be coupled across segment joints.

960-2.2.1.7 "O"-Rings:

1. "O"-rings with cross section diameters less than or equal to 0.25 inches and compression seals with thicknesses less than or equal to 0.25 inches for use with segmental duct couplers, anchorage caps and other similar components shall conform to the requirements of Table 960-3.

Table 960-3 "O"-Ring and Compression Seal Material Properties (cross section diameter or thickness ≤ 0.25 in)	
Mechanical Properties	
Shore hardness, ASTM D2240	50-75
Ultimate elongation %, ASTM D412	250% min.
Tensile strength, ASTM D412	1400 psi min.
Accelerated Testing	
Thermal Deterioration 70 hours @ 257° F, ASTM D573	
Change in tensile strength	± 30%
Change of elongation	-50%
Change of hardness	± 15 points
Compression Set Method B 22 hours @ 257° F, ASTM D395	50%
Volume change due to absorption of H_2O, Method D, for 70 hours @ 212°F, ASTM D 471	+ 10%
Environmental Resistance	
Ozone Resistance Exposure Method B, ASTM D1171 or Method B- Procedure B4, ASTM D1149	Pass
Low Temp. Non-brittle after 3 Min. @ -40°F, ASTM D2137	Pass

2. "O"-rings with cross section diameters greater than 0.25 inches and compression seals with thicknesses greater than 0.25 inches for use with segmental duct couplers, anchorage caps and other similar components, shall conform to the requirements in Table 960-3 with the additions and modifications in Table 960-4.

Table 960-4 "O"-Rings and Compression Seal Material Properties (cross section diameter or thickness > 0.25 in)
Mechanical Properties

Shore hardness, ASTM D2240	30-60
Tensile strength, ASTM D412	600 psi min.
Compression Set Method B 22 hours @ 257° F, ASTM D395	60%

3. Compression Force - Maximum force to compress an "O"-ring or compression seal to its final compressed position shall not be greater than 25 psi times the area encircled by "O"-ring or seal.

4. Voided Area - Compression seals must accommodate material flow within its own cross sectional area by using a hollow or voided design.

960-2.2.1.8 Heat Shrink Sleeves:

1. Heat shrink sleeves shall have unidirectional circumferential recovery and be sized specifically for the duct size being coupled.

2. Use sleeves with a crosslinked polymer, typically polyolefin backing for grouted applications and sleeves with a high-density polyethylene or polypropylene backing for flexible filler applications.

3. Use adhesive with the same bond value to steel and high-density polyethylene or polypropylene materials.

4. Heat shrink sleeves shall have an adhesive layer that meets the requirements of the following table:

Table 960-5
Heat Shrink Sleeve Adhesive Layer Minimum Requirements

Property	Test Method	Minimum Requirements	
		Grouted Applications	Flexible Filler (Internal and External Applications)
Softening Point	ASTM E28	162ºF	256ºF
Lap Shear at 73ºF	ISO 21809-3	87 psi	44 psi
Tensile Strength	ASTM D638	2,900 psi	3,190 psi
Hardness	ASTM D2240	46 Shore D	55 Shore D
Elongation	ASTM D638	600%	600%
Volume Resistivity	ASTM D257	3.9 x 10^16 ohm-inch	3.9 x 10^16 ohm-inch
Adhesion Strength at 73ºF	ISO 21809-3	5-20 lbf/inch	28 lbf/inch
Impact Resistance	ISO 21809-3	Pass	15 J
Indentation Resistance	ISO 21809-3	Pass	0.026 inch
Cathodic Disbondment @ 73ºF, 28 days	ISO 21809-3	0.5 inch*radian	< 0.4 inch
Backing Thickness	-	0.025 inch	0.035 inch
Adhesive Thickness	-	0.035 inch	0.055 inch
Operating Temperature	-	122°F	212°F

5. Install heat shrink sleeves using procedures and methods specified in the manufacturer's instructions.

6. Do not use heat shrink sleeves with properties meeting the requirements for grouted applications for applications using flexible filler.

7. Do not use heat shrink sleeves with properties meeting the requirements for flexible filler applications for applications using grout.

960-2.2.2 Attachments:

960-2.2.2.1 Anchorage Caps:

1. Provide permanent anchorage caps made of stainless steel, nylon, polyester, or Acrylonitrile Butadiene Styrene (ABS).

2. Seal Anchorage cap with "O"-ring seals or precision fitted flat gaskets placed against the bearing plate.

3. Provide holes of 3/8 inch minimum diameter at the top and bottom of the cap. The holes must be suitable for filler venting, draining water, and inspection of the content inside the anchorage cap from the top, bottom or front of the anchorage cap as appropriate (e.g. anchorage caps not accessible from the front after filler injection must have a vent at the top of the cap). Anchorage caps may be fabricated with top/bottom holes on both the front face and outside perimeter the cap to facilitate venting, draining, and inspection.

4. Anchorage caps shall have a minimum pressure rating of 150 psi.

5. Stainless steel bolts shall be used to attach cap to anchorage.

6. Certified test reports documenting steel chemical analysis shall be submitted when stainless steel anchorage caps are used.

960-2.2.2.2 Inlets, Outlets, Drains, Ports, Valves, and Plugs:

1. Provide permanent inlets, outlets, drains, ports, valves, and threaded plugs made of nylon, high-density polyethylene or polypropylene materials, or stainless steel.

2. For unbonded post-tensioning systems using flexible filler, provide permanent inlets, outlets and drains made from steel. Provide temporary inlets, outlets, drains and valves made from brass or steel.

3. All inlets, outlets, drains and ports shall have pressure rated mechanical shut-off valves or plugs. Mechanical shut-off valves must be 1/4 turn ball valves.

4. Inlets, outlets, drains, ports, valves, and plugs shall have a minimum pressure rating of 150 psi.

5. Inlets, outlets and ports shall have a minimum inside diameter of 3/4 inches for strand and 3/8 inches for single bar tendons and four-strand ducts.

6. Drains shall have a minimum inside diameter of 3/8 inches. Locate drains, and inlets and outlets serving as drains, at the bottom of the duct cross section.

7. Specifically designate temporary items, not part of the permanent structure, on the PT system shop drawings.

960-2.3 Steel Reinforcing:

960-2.3.1 Mild:

1. Reinforcing steel shall conform to Section 415 and Section 462.

2. Test typical local zone reinforcement for compliance with AASHTO LRFD Bridge Design Specifications and AASHTO LRFD Bridge Construction Specifications, as applicable. Include reinforcement details in the PT system shop drawings submitted for approval.

960-2.3.2 Prestressing:

960-2.3.2.1 Strand: Prestressing strands shall be in accordance with Section 933.

960-2.3.2.2 Bar:

1. Prestressing bars shall be in accordance with Section 933.
2. Bar couplers shall be in compliance with AASHTO LRFD Bridge Design Specifications and AASHTO LRFD Bridge Construction Specifications.
3. Test bar couplers in accordance with AASHTO LRFD Bridge Construction Specifications or the European Assessment Document Post-Tensioning Kits for Prestressing of Structures (EAD 160004-00-0301, September 2016 Edition). For bar couplers that will be used for tendons with flexible filler, test bar couplers in accordance with the EAD 160004-00-0301 Section C.3 Resistance to Fatigue.
4. Use only spherical nuts to anchor bars at bearing plates.

960-2.4 PT System Materials:

1. Use material specifications in this Section for all PT system components and subcomponents.
2. Use only virgin material for all non-ferrous components.
3. Test only samples taken from finished product as applicable.

960-2.4.1 Nylon: Use one of the following cell classes according to ASTM D5989:

1. S-PA0141 – weather resistant.
2. S-PA0231 – heat stabilized.
3. S-PA0401 – ultimate strength not less than 10,000 psi with UV stabilizer added.

960-2.4.2 Stainless Steel: Conform to the following:

1. ASTM A240 Type 316 - for metallic components other than bolts.
2. ASTM F593 Type 316 - for bolts.

960-2.4.3 Polypropylene: Conform to all of the following:

1. Non-colored, unfilled polypropylene according to ASTM D4101 with a cell class range of PP0340B44541 to PP0340B67884.
2. Contains antioxidants with a minimum Oxidative-Induction Time (OIT) according to ASTM D3895 of not less than 20 minutes.
3. Contains a non-yellowing light stabilizer.
4. Remolded finished material has a minimum failure time of 100 hours when tested for stress crack resistance using ASTM F2136 at an applied stress of 600 psi.

960-2.4.4 High-density Polyethylene: Conform to all of the following:

1. Smooth pipe is to meet the requirements of ASTM D3350 with a minimum cell class of 445574C. All other HDPE components are to meet the requirements of ASTM D3350 with the values of the first four digits of the cell class meeting a minimum of 4455, be composed of a resin listed in the Plastic Pipe Institute's Technical Report 4 for Hydrostatic design basis and have a code letter designation of "C" per ASTM D3350.
2. Contains antioxidants with a minimum Oxidative-Induction Time (OIT) according to ASTM D3895 of 40 minutes.
3. Remolded finished material has a minimum failure time of 24 hours when tested for stress crack resistance using ASTM F2136 at an applied stress of 600 psi.

960-2.4.5 Elastomer Sleeves: Conform to all of the following:

1. Meet requirements of ASTM D1171 using Ozone Chamber Exposure Method B (no cracks permitted under 2X magnification) or ASTM D1149 Method B- Procedure B4 (no cracks permitted under 2X magnification). Do not include polyester reinforcement in the test specimen.

2. Manufactured using an elastomeric polymeric material that is compatible with concrete, the PT system components to which the sleeves will be attached, and the filler material and filler material installation process. Identify the applicable ASTM specifications that the sleeve material complies with.

960-3 System Approval Requirements.

960-3.1 Independent Testing: Use independent laboratories meeting the credentials described in this Section to perform all testing, other than field testing, and to submit certified test reports for materials and components. Certification may be performed by a qualified independent laboratory outside of the United States, only if the facility is pre-approved by the State Materials Office.

Conform all testing procedures used for materials or components to applicable American Society of Testing and Materials (ASTM) and International Federation of Structural Concrete (fib) Specifications or as modified in this Section.

960-3.1.1 Material Laboratory: Test plastic components in a certified independent laboratory accredited through the laboratory accreditation program of the Geosynthetic Accreditation Institute (GAI), the American Association for Laboratory Accreditation (A2LA) or qualified by an ISO 17025 accreditation agency using personnel with documented experience running the required test methods.

960-3.1.2 Component and System Laboratory: Test individual components and the PT system as a whole witnessed by and/or performed in a certified independent laboratory audited by the AASHTO Materials Reference Laboratory (AMRL), or with an AASHTO R18 Accreditation as set forth by the AASHTO Highway Subcommittee on Materials or qualified by an ISO 17025 accreditation agency using personnel with documented experience running the required test methods.

960-3.1.3 System Testing: In lieu of performing PT system tests witnessed by and/or performed in a certified independent laboratory, the PT system tests may be performed at the project site and witnessed by the Engineer.

960-3.2 Testing Requirements:

960-3.2.1 Component and System Tests: Corrugated duct, smooth duct and all associated components that are used for both internal and external PT systems, e.g. couplers, anchorages, inlets, outlets, drains, ports, valves, plugs, etc., shall meet the requirements of fib Technical Report Bulletin 75 titled, Polymer-Duct Systems for Internal Bonded Post-Tensioning, Performance Level 2 (PL2), with modifications as shown in Table 960-6.

Table 960-6 Required Component and System Tests					
Reference to fib Bulletin 75			Required Tests for each PT System Type[1]		
Procedures	Appendix	Test Description	Internal PT System with Grout	Internal PT System with Flexible Filler	External PT System with Flexible Filler
Component Assessment	A.1	Dimensional requirement	Yes	No	No
	A.2	Stiffness of duct	Yes[2]	No	No
	A.3	Longitudinal load resistance	Yes	Yes	Yes
	A.4	Lateral load resistance	Yes	No	No
	A.5	Flexibility of duct system	Yes	Yes	No
	A.6	Leak tightness of duct system	Yes	Yes	No
	A.7	Concrete pressure on duct	Yes[3]	No	No
	A.8	Wear resistance of duct	Yes	No	No
	A.9	Wear resistance of duct under sustained load	Yes	No	No
	A.10	Bond behavior of duct	Yes	No	No
	A.11	Precast segmental duct coupler system	Yes[4]	Yes[4]	No
	A.12	Fracture resistance of duct	No	No	No
System Assessment	B.1	Leak tightness of anchorage-duct assembly	Yes[5]	Yes[5]	Yes[5]
	B.2	EIT performance of duct system	No	No	No
	B.3	EIT performance of anchorage-duct assembly	No	No	No
	B.4	Full scale duct system assembly	Yes[5][6]	Yes[5][6]	Yes[5][6]
	B.5	Leak tightness of assembled duct system	Yes[5][6]	Yes[5][6]	No

(1) Yes = Test is required; No = Test is not required.
(2) Do not preload strand into duct prior to testing.
(3) Identify duct as meeting Performance Class I or II criteria.
(4) Use an epoxy compound meeting the requirements of Section 926, Type AB.
(5) Perform tests on the largest assembly and the smallest assembly for each family of PT systems. A family of PT systems is defined a group of PT strand/bar assemblies of various sizes using common anchorage devices and design.
(6) For each test, use a PT system assembly consisting of at least one of each component and connection type required to install a tendon from anchorage cap to anchorage cap. For bar tendon systems, use between 15 and 50 feet of duct with a straight profile.

960-3.2.2 Filler Containment Assembly Pressure Test: In addition to the other testing specified in this Section, test all filler containment assemblies, i.e., anchorages, anchorage caps, inlets, outlets, drains, ports, valves, plugs, etc., for all system sizes as follows:

1. Assemble the anchorage and anchorage cap with all required filler injection attachments.
2. Seal the opening in the anchorage where the duct/trumpet connects.
3. Condition the assembly by maintaining a pressure of 150 psi in the system for three hours.

4. After conditioning, lock off the air supply to the assembly.

5. After lock off, the assembly must sustain 150 psi internal pressure for five minutes with no more than 15 psi, or 10%, reduction in pressure.

This test may be combined with the External Duct Systems Pressure Test for external PT systems.

960-3.2.3 External PT Systems Pressure Test: In addition to the other testing specified in this Section, test all sizes of external PT systems as follows:

1. Prepare a system assembly consisting of at least one of each component and connection type required to install a tendon from anchorage cap to anchorage cap using between 15 and 50 feet of duct with a straight profile.

2. Condition the assembly by maintaining a pressure of 100 psi in the system for three hours.

3. After conditioning, lock off the air supply to the assembly.

4. After lock off, the assembly must sustain 100 psi internal pressure for five minutes with no more than 10 psi reduction in pressure.

960-3.2.4 Vacuum Test for Internal and External PT Systems with Flexible Filler: In addition to the other testing specified in this Section, test all sizes of internal PT systems with flexible filler and all external PT as follows:

1. Prepare a system assembly consisting of at least one of each component and connection type required to install a tendon from anchorage cap to anchorage cap using between 15 and 50 feet of duct Do not cast any component into concrete.

2. Condition the assembly by maintaining a 90% vacuum in it for 1 hour.

3. After conditioning, lock off the air supply to the assembly.

4. After lock off, the assembly must sustain a 90% vacuum for 5 minutes with no more than a 10% loss of vacuum.

960-3.3 Standard Tendon Sizes: Develop and test PT systems for the sizes and types shown in the Contract Documents.

960-3.4 System Modifications: Contact the Engineer for direction before changing any materials or components of a PT system that has been approved by the Engineer for use on the project. Repeat all appropriate material, component, and entire system tests if the manufacturer and/or model of any major component, as defined in 960-2, is modified or replaced, excluding local zone reinforcement.

960-3.5 Component Samples: Furnish all required material samples to laboratories for testing and to the Department as requested, at no cost to the Department.

960-3.6 Calculations, Shop Drawings, Test Reports, and Certification: Show fully detailed shop drawings of all component configurations, connections, anchorages, inlets, outlets, drains, high point inspection port details, anchorage inspection details, permanent anchorage caps, application limits of the PT system, and installation procedures of components. On the first page of each PT system shop drawing set, provide a list of all system components in tabular format that includes the following information, at a minimum: part/item number, description, material, manufacturer and model. The manufacturer need not be identified for common off-the-shelf accessories as defined in 960-2. Submit details of typical local zone reinforcement in the PT system shop drawings signed and sealed by a Specialty Engineer. Indicate that all major PT system components, as defined in 960-2, are stamped with the following:

1. Manufacturer’s name

2. Trademark model number

3. Size corresponding to catalog description on PT system drawings.

For each PT system, submit a package that includes calculations, shop drawings, test reports, proof of current laboratory accreditations, and all material and component certifications required throughout this Section. Proof of current laboratory accreditation must specifically indicate applicable accreditation categories related to PT systems.

Include a cover letter with the package signed by an officer of the PT system supplier (vendor) certifying that:

1. The submitted PT system, as a whole and all of its individual components, meet or exceed all material and component/system requirements of this Section, as demonstrated by the submittal.

2. All testing required by this Section was performed as defined in 960-3.1 and that all tests were performed to applicable ASTM and fib Specifications.

3. The PT system meets the requirements of Section 462.

SECTION 962
STRUCTURAL STEEL AND MISCELLANEOUS METAL ITEMS (OTHER THAN ALUMINUM)

962-1 General.

This Section covers the material and fabrication requirements for structural steel and miscellaneous metal components. All steel must be melted and manufactured in the United States and meet Section 6-5.2. All overhead cantilevers, monotubes, trusses and gantries, and bridge components (including steel castings, steel forgings, and bearing material) supplied under this Specification shall be from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the Department's Production Facility Listing must meet the requirements of Section 105. Provide certifications that meet the applicable section and 962-12.

962-2 Structural Steel.

962-2.1 Structural Steel Materials: Provide structural steel for bolted or welded construction that meets the requirements of Table 962-1.1 and 962-1.2 when impact testing is specified. Grade HPS 70W shall not be substituted for Grade HPS 50W. Weathering steel shall not be substituted for non-weathering steel without Engineer approval.

Do not apply heat treatment unless approved by the Engineer. When galvanizing is specified, provide galvanizing in accordance with 962-11.1.

Table 962-1
Structural Steel Materials

Product	ASTM	Grade/Style	Reportable Properties	Supplementary Requirements
Plate	A709	36	Composition, Yield Strength, Tensile Strength, Elongation, Killed	None
		50		
		50S		Carbon Equivalency
		50CR		Heat-treating temperatures
		50W	Composition, Yield Strength, Tensile Strength, Elongation, Killed, Fine Grain	Corrosion Resistance Index
		HPS 50W		Corrosion Resistance Index, Heat Treatment Temperatures
		HPS 70W		

962-2.2Impact Requirements: Structural steel subject to tensile stress for main load-carrying members shall meet the impact requirements listed in Table 962-2. Mill test reports shall identify average impact test values. Provide certifications that meet this section and 962-12.

For non-fracture and fracture critical tension components, provide structural steel in accordance with ASTM A709.

Table 962-2 Requirements for Impact Testing Structural Steel					
Product	ASTM	Grade	Zone	Minimum Average Energy (ft*lbf)	
				Non-Fracture Critical	Fracture Critical
Structural Steel	A709	36	1	15 at 70°F	25 at 70°F
		50 50W 50S		15 at 70°F (≤ 2.0"t) 20 at 70°F (> 2.0"t)	25 at 70°F (≤ 2.0"t) 30 at 70°F (> 2.0"t)
		50CR		15 at 70°F	25 at 70°oF
		HPS 50W		20 at 10°F (≤ 2.0"t) 25 at 50°F (> 2.0"t)	30 at 10°F (≤ 2.0"t) 35 at 50°F (> 2.0"t)
		HPS 70W		25 at -10°F	35 at -10°F
Structural Steel Tubing	A500	B, C, D		15 at 70°F	25 at 70°F
	A501	A, B			
	A847	Round, Square, Rectangle, Special			
Note: If yield ≥15 ksi above specified grade, test temperature must drop 15°F for each 10 ksi above grade.					

962-3 Steel Castings.

Provide carbon steel and corrosion resistant castings in accordance with this section and Table 962-3.

962-3.1 Carbon Steel Castings: Perform heat treatments by annealing, normalizing, normalizing & tempering, or quenching & tempering after castings have been allowed to cool from the pouring temperature to below the transformation temperature range as regulated by the use of pyrometers. Class 1 castings shall be used if post-weld heat treatment is specified in the contract documents.

962-3.2 Corrosion Resistant Steel Castings:

Perform heat treatments by air cooling and tempering; or annealing as defined in ASTM A743 Table 1.

Table 962-3 Requirements for Steel Castings					
Product	Standard	Grade	Class	Reportable Properties	Supplementary Requirements
Carbon Steel	ASTM A27	65-35, 70-36	1, 2	Composition, Tensile, Class	None
Corrosion Resistant Steel	ASTM A743	CA 15M	All	Composition, Heat Treatment	S11, S12
	AASHTO M 163				

962-4 Steel Forgings.

Provide carbon steel and alloy steel forgings from which pins, rollers, trunnions, shafts, gears, or other forged parts are fabricated in accordance with this section and Table 962-4.

The manufacturer may elect to choose from any of the class specific heat treatments identified in the Table 962-4, provided that the controlling cross-sectional thickness meets mechanical property test requirements. Retreatment by re-austenitizing a lot is allowed up to three times when the mechanical properties have not been met. Re-testing of the mechanical properties is required on any lot subject to retreatment.

Table 962-4
Requirements for Steel Forgings

Product	Standard	Class	Reportable Properties	Supplementary Requirements
Steel Forgings	ASTM A668	C, D, F, G	Composition, Tensile, Yield, Elongation, Hardness	S7
	AASHTO M 102			

962-5 Iron Castings.

Provide iron castings that conform to the requirements of this section and Table 962-5. When galvanizing is specified in the contract, galvanize in accordance with 962-11.

962-5.1 Gray Iron Castings: Provide gray iron castings that conform to the requirements of this section and Table 962-4. AASHTO HL-93 load testing may be substituted for tensile testing when specified in the contract documents. When Alternative G castings are specified, provide a composition that precludes the possibility of embrittlement during the normal thermal cycle of hot-dip galvanizing.

962-5.2 Ductile Iron Castings: Perform full ferritizing anneal to remove carbides or stabilized pearlite. AASHTO HL-93 load testing may be substituted for tensile testing when specified in the contract documents.

962-5.3 Malleable Iron Castings: Perform heat treatments in the same production furnace and in the same cycles as the castings they represent. Produce a microstructure consisting of temper carbon nodules distributed through a ferritic matrix and free of excessive pearlite, massive carbides, and primary graphite. When critical sections of the production castings differ appreciably from that of the central portion, the time cycle for tempering may be altered from that of the production lot in order to obtain similar microstructures, or hardness, or both.

When Alternative G castings are specified, provide a composition that precludes the possibility of embrittlement during the normal thermal cycle of hot-dip galvanizing, or provide heat treatment that immunizes the casting against embrittlement during the normal thermal cycle of hot-dip galvanizing.

Table 962-5 Requirements for Iron Castings				
Product	Standard	Grade/Class	Reportable Properties	Supplementary Requirements
Gray Iron Traffic Service	AASHTO M 105 & AASHTO M 306	35B	Tensile*	None
Gray Iron Machinery	AASHTO M 105	30	Tensile	None
Ductile Iron	ASTM A536	60-40-18	Tensile*, Yield, Elongation, Heat Treatment	Additional Tensile test for castings > 1,000 lbs.
Malleable Iron	ASTM A47	30518 [24118]	Tensile, Yield, Elongation, Heat Treatment	None
*AASHTO HL-93 may be substituted for tensile testing of vaned gratings, when specified in the contract.				

962-6 Bolts, Nuts and Washers Not Designated as High-Strength.

Provide bolts, nuts, and washers not designated as high strength meeting the requirements listed in this Section and Table 962-6. When galvanizing is specified in the contract documents, provide galvanizing in accordance with 962-11.3.1.

Use double nuts, when ordinary rough or machine bolts are specified in the Contract Documents. Bolted assemblies shall be made of similar coating composition. When weathering material is used, provide the entire assembly in weathering steel. Bolts meeting the requirements of ASTM A193, washers meeting the requirements of ASTM F844 and nuts meeting the requirements of ASTM A194 or AASHTO M292 may be used with the Engineer's approval.

Table 962-6 Bolts, Nuts, and Washers Not Designated as High-Strength				
Product	Standard	Grade	Style	Reportable Properties
Bolts	ASTM A307	A, B	Heavy Hex, Threaded Rod	Size, Composition, Hardness, Tensile
	ASTM A449	1, 3	Hex, Threaded Stud	Size, Composition, Tensile, Proof Load, Hardness
	ASTM F593	Group 2 316 or 316L	Condition A CW1 or SH1	Alloy, Group, Condition
	ASTM A193*	B7, B16	Any	Size, Composition, Hardness, Heat

Table 962-6 Bolts, Nuts, and Washers Not Designated as High-Strength				
Product	Standard	Grade	Style	Reportable Properties
				Treatment, Macroetch results
Nuts	ASTM A563	A	Hex	Size, Composition, Proof Load, Hardness
		C, C3, DH, DH3	Heavy Hex	
	ASTM F594	Group 2 316 or 316L	CW	Alloy, Group, Condition
	ASTM A194*	2, 2H	Hex, Heavy Hex	Composition, Hardness, Proof Load
	AASHTO M 292*	2, 2H	Hex, Heavy Hex	Size, Composition, Hardness, Heat Treatment, Macroetch results
Washers	ASTM F436	1, 3	Circular, Beveled, Clipped, Extra Thick	Size, Hardness
	N/A	316 or 316L	Any	Alloy, Size
	ASTM F844*	Plain	Round, Miscellaneous	Size
	ASTM A36	All	N/A	Killed, Thickness
Shims	ASTM A1011	Any	Any	None
	ASTM A109	Any	Any	None
	ASTM B36	Brass	Any	None

962-7 High-Strength Bolts, Nuts, Washers and Direct-Tension-Indicator (DTI) Devices.

Provide high-strength bolts, nuts, washers and DTI devices in accordance with this Section and Table 962-7. High-strength bolts shall have identifying marks meeting ASTM F3125 Table 2 and ASTM A563. High-strength bolted assemblies shall be made of similar coating composition. When galvanizing is specified in the contract documents, provide galvanizing in accordance with 962-11.3.2. Bolts meeting the requirements of ASTM F3125 Grade A490, washers meeting the requirements of ASTM F844, and nuts meeting the requirements of ASTM A194 or AASHTO M 292 may be used with the Engineer's approval.

Table 962-7 Requirements for High-Strength Steel Fastener Assemblies					
Products	Standard	Grade	Type/ Style	Reportable Properties	Supplementary Requirements
Bolts	ASTM F3125	A325	Heavy Hex	Size, Composition, Tensile, Proof Load, Hardness,	None
		A490*		Size, Composition, Tensile, Proof Load, Hardness, Magnetic Particle, Carburization/ Decarburization	
	ASTM A193	B7, B16	Any	Size, Composition, Hardness, Heat Treatment, Macroetch results	S5
Nuts	ASTM A563	DH, DH3	Heavy Hex	Size, Composition, Proof Load, Hardness	S1, S2 min. 89 HRB or 180 HB
	ASTM A194*	2H	Heavy Hex	Size, Composition, Hardness	Max HRC32
	AASHTO M 292*	2H	Heavy Hex	Size, Composition, Hardness, Heat Treatment, Macroetch results	Max HRC32
Washers	F436	Circular, Beveled, Clipped, Extra Thick	1, 3	Size, Hardness	None
	F844*	Round, Miscellaneous	Plain	Size	None
	ASTM A709	36, 50	Any	Yield, Tensile, Elongation, Killed	None
DTI Devices	F959	A325	1	Size, Composition, Compression Load, Hardness	None
			3	Size, Composition, Compression Load, Hardness, Corrosion Resistance Index	
*Requires Engineer Approval.					

962-8 Anchor Rods and Bridge Bearing Materials.

962-8.1 Bearing and Masonry Plate: Meet the requirements of Table 962-8. Masonry plates and bearings shall be welded in accordance with AASHTO/AWS D1.5 Bridge Welding Code. When galvanizing is specified meet the requirements of 962-11.1.

Table 962-8
Requirements for Bearings and Masonry Plate

Product	ASTM	Grade	Style	Reportable Properties	Supplementary Requirements
Plate	A709	50W	All	Yield, Tensile, Elongation, Killed, Fine Grain	Corrosion Resistance Index
Laminates	A240	316	Gage 16	Yield, Tensile, Elongation, Hardness	None
	A1011	36	HSLAS, Class 1	Designation, Style	None
	A36	All	All	Yield, Tensile, Elongation, Killed	None

962-8.2 Anchor Rods and Bearing Hardware: Provide anchor rods and other bearing hardware in accordance with this section and Table 962-9. All fastening components shall be made of similar composition. When galvanizing is specified in the contract documents, provide galvanizing in accordance with Section 962-11.3.1. Anchor rods meeting the requirements of ASTM A307, washers meeting the requirements of ASTM F844, and nuts meeting the requirements of ASTM A194 may be used with the Engineer's approval.

Table 962-9
Requirements for Anchor Rods and Bearing Hardware

Product	ASTM	Grade	Style	Reportable Properties	Supplementary Requirements
Bolts	F1554	36	Threaded Rod	Lot, Size, Tensile	None
		55		Lot, Size, Tensile, Carbon Equivalency	S1
		105		Lot, Size, Tensile, Carbon Equivalency	S3
	A307*	A, B	Threaded Rod	Size, Composition, Hardness, Tensile	S1
Nuts	A563	DH	Heavy Hex	Size, Composition, Proof Load, Hardness	None
	A194*	2H	Heavy Hex	Size, Composition, Hardness	None
Washers	F436	1, 3	Circular, Beveled,	Size, Hardness	None

Table 962-9 Requirements for Anchor Rods and Bearing Hardware					
Product	ASTM	Grade	Style	Reportable Properties	Supplementary Requirements
			Clipped, Extra Thick		
	F844*	Plain	Round, Miscellaneous	Size	None
Plate	A36	All	All	Yield, Tensile, Elongation, Killed	None
Shim	A653	All	Min. G30	Grade	None
	A1008 A36	All	A153, F2329	None	None
*Requires Engineers Approval.					

962-9 Overhead Signs.

Provide overhead sign materials in accordance with this section Table 962-2, and Table 962-10. When galvanizing is specified, meet the requirements of 962-11.1. Produce welds using E7018 electrode, in accordance with AWS D1.1 Structural welding Code.

Table 962-10 Requirements for Overhead Signs					
Product	Standard	Grade	Type/ Style	Reportable Properties	Supplementary Requirements
Upright Pipe	API 5L	X42R, X42N, X42M, X46N, X46M, X52N, X52M, X56N, X56M, X60N, X60M, X65M, X70M	PSL2	Killed, Fine Grain, Tensile, CVN Test	N/A
	A500	B, C	Round Structural	Composition, Yield, Tensile, Elongation	UT Seam Weld, (per API 5L) CVN Test per 962-2
Chords	A500	B, C	Round Structural	Composition, Yield, Tensile, Elongation	N/A
Plate, Angles &	A709	50	Plates & Shapes	Composition, Yield, Tensile, Elongation	N/A
	A36	36			Yield > 50ksi

Table 962-10 Requirements for Overhead Signs					
Product	Standard	Grade	Type/ Style	Reportable Properties	Supplementary Requirements
Handhole Frame					
Poles	A1011	50, 55, 60, 65	Any	Designation, Grade	N/A
	A572	50, 55, 60, 65	1, 2, 3, 5	Composition, Tensile, Type, Killed	N/A
	A595	A, B	Any	Composition, Tensile, Type, Killed	N/A

962-10 Miscellaneous Metal Items.

962-10.1 General: Unless otherwise specified in the contract documents, provide miscellaneous metal components in accordance with this section and Table 962-11, Table 962-12, Table 962-13, or Table 962-14. Structural tubing subject to tensile stresses, as defined in Section 460, shall meet Table 962-2.2 for tension components, Zone 1. Welding shall be done in accordance with the most current AWS D1.1 structural welding code. When galvanizing is specified in the contract documents, provide galvanizing in accordance with the contract documents.

Requirements for concrete reinforcement are contained in Section 931.

Requirements for steel guardrail are contained in Section 967.

Table 962-11 Requirements for Miscellaneous Metals				
Product	Standard	Grade	Type/ Style	Reportable Properties
Steel Sheet Piling	A328	All	Cold Rolled, Heat Treated	Composition, Tensile, Killed
	A572	42, 50, 55, 60, 65	1, 2, 3, 5	Composition, Tensile, Size, Killed
	A690	All	All	Composition, Tensile, Killed
Steel Pipe Piling	A252	3	All	Composition, Tensile, Size
	API 5L	X46, X52, X56, X60, X65, X70	PSL1	Tensile
			PSL2	Killed, Fine Grain, Tensile
Structural Tubing	A500	Round	B, C	Composition, Tensile, Flattening Test, Impact (Zone 1), Size
		Shaped		Composition, Tensile, Impact (Zone 1), Size
	A501	Square, Round, Rectangular, Special	A, B	Composition, Tensile, Impact (Zone 1), Size

Table 962-11 Requirements for Miscellaneous Metals				
Product	Standard	Grade	Type/ Style	Reportable Properties
	A847	Round	Welded, Seamless	Composition, Tensile, Flattening, Impact (Zone 1), Size
		Square, Rectangle, Special	Welded, Seamless	Composition, Tensile, Impact (Zone 1), Size
Pipe Railing	A53	A, B	E, S	Composition, Mechanical Testing (Tensile, Bend, Flattening), Size

962-10.2 Field Splice Filler Materials: Provide field splice filler materials in accordance with the contract documents. If unspecified and less than 3/16 inches thick filler splice materials in accordance with this section and Table 962-12. Filler plates may also meet the appropriate grades specified in 962-2. When galvanized plate is specified, galvanize material in accordance with 962-11

Table 962-12 Requirements for Field Splice Filler Materials				
Product	Standard	Grade	Type/ Style	Reportable Properties
Filler Sheet	A1011	50	HSLAS, Class 1	Designation, Grade

962-10.3 Fencing Material: Provide fencing materials in accordance with this Section and Table 962-13. When galvanizing is specified, provide galvanizing in accordance with the contract documents.

Table 962-13 Material Requirements for Fencing				
Product	Standard	Grade / Type	Style	Reportable Properties
Fabric	A116	60	No. 9	Breaking Strength, Coating Weight
		175	No. 12-1/2	
	A584	175	No. 12-1/2	
	M181	1, 2, 4	No. 9	
	A392	All	No. 9	
	A491	All	No. 9	
	F668	All	No. 9	
Posts	A702	50	Carbon, Rail	Tensile or Hardness
Pipe, Tube	A53	A, B	E, F, S	Grade, Finish
	F1083	Schedule 40	High Strength	Schedule

Table 962-13 Material Requirements for Fencing				
Product	Standard	Grade / Type	Style	Reportable Properties
	F1043	1C	All	Group, Coating, Type
		1A	High strength	
Beam	A36	36	All Shapes	Grade, Killed
	A572	42		
	A992	50		
Sheets	A1011	36, 45, 50	HSLAS, HSLAS-F, SS	Designation, Style

962-10.4 Steel Grates: Provide steel grating in accordance with this section and Table 962-14. When vaned gratings are specified, AASHTO HL-93 load testing may be substituted for tensile testing when specified in the contract documents. When Alternate G is specified, provide galvanizing in accordance with 962-11.1.

Table 962-14 Requirements for Steel Grating				
Product	Standard	Grade	Type/ Style	Reportable Properties
Steel Grating	A242	50	1	Composition, Tensile*, Killed
	A572		1, 2, 3, 5	Composition, Tensile*, Size, Killed
	A588		A, B, K	Composition, Tensile*, Fine Grain
	A1011	Any	SS, HSLAS, HSLAS-F	Designation, Style
* AASHTO HL-93 may be substituted for tensile testing for vaned gratings when specified.				

962-11 Galvanizing.

962-11.1 Plates, Structural Shapes, Bars, and Strip: When galvanizing is specified in the Contract Documents for ferrous metal products, provide galvanizing in accordance with the requirements of ASTM A123 or AASHTO M111. Zinc composition shall meet “Intermediate Grade” in accordance with ASTM B6 and Table 962-15.

Table 962-15 Requirements for Galvanizing Bath Composition			
Product	Zinc (Zn)	Lead (Pb)	Tin (Sn)
Galvanizing Bath	≥ 99.00%	≤ 0.50%	≤ 0.10%

962-11.2 Castings: When Alternative G castings are specified in the contract documents, provide galvanizing in accordance with the requirements of ASTM A123 or AASHTO M111. Zinc composition shall meet 962-11.1.

962-11.3 Fasteners and Hardware:

962-11.3.1 Fasteners and Hardware Designated Not High-Strength: When zinc coating is required in the contract documents provide galvanizing of steel or malleable iron in accordance with the requirements of ASTM A153.

962-11.3.2 Fasteners and Hardware Designated as High-Strength: When zinc coating is required in the Contract Documents, provide galvanizing in accordance with Table 962-16. Coating of ASTM F3125, A490 bolts is prohibited. Bake all hot dipped or electroplated bolt, rod, or bar with a tensile strength greater than or equal to 150 ksi to remove any residual hydrogen.

Table 962-16
Coating Requirements for Fastener and Hardware Designated as High-Strength

Product	ASTM	Grade	Type/Style	Coating Finish
Bolts	F3125	A325	1	ASTM B695, Class 55 ASTM F2329
		A490	All	Do Not Galvanize
Anchor Rods	F3125	A325	1	ASTM B633 SC 3, Type II
		A490	All	Do Not Galvanize
	F1554	105	All	ASTM B633 SC 3, Type II
Anchor Rods	F1554	36, 55	All	ASTM B695 Class 55 ASTM F2329
Nuts	A563	A, C, D, C3, DH, DH3	Hex, Heavy Hex	
	A194	1, 2	All	
Washers	F436	Circular, Beveled, Clipped, Extra Thick	1	
	F844	Round, Miscellaneous	A	
DTI Devices	F959	A325	1	

962-12 Certifications and Verification.

962-12.1 General: Provide certifications for steel directly from the Mill. Mill certifications shall show compliance to the specification and include the reportable properties and supplementary requirements from the applicable sections listed above.

When secondary processing, or testing has occurred, in addition to the mill certificate, provide a certified mill analysis signed by a quality control representative that show compliance with and the test results of the applicable sections listed above.

When material meeting “Buy America” is specified, the mill certification or certified mill analysis shall identify that the included material meets the Source of Supply-Steel requirements in Section 6.

SECTION 965
GENERAL PROVISIONS FOR ALUMINUM ITEMS (INCLUDING WELDING)

965-1 General.

This Section covers the material and fabrication requirements for aluminum components. Provide aluminum light poles and Gantry J-arms from Producers who are approved in one of the following fabrication categories:

1. American Institute of Steel Construction, Highway Component Manufacturer
2. American Welding Society, Certified Welding Fabricator
3. Canadian Welding Bureau, Fusion Welding of Aluminum (W47.2).

965-2 Fabrication.

Provide fabricated components in accordance with AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, the Design Plans, and this section. Verify the strength of each Lot by tensile test. Alternate testing will not be accepted. Protect against damage and marring during transit and delivery. Provide an anodic coating (minimum 0.0002 inch) and chromate seal all hardware.

An American Welding Society certified welding inspector must visually inspect all welds for final approval. A certifying statement from the welding inspector must be provided with the component. The document must identify the project information, date of inspection, welding inspector name, and inspector certification number.

Table 965-1
Material Requirements for Aluminum Components

Product	Test Method	Alloy/Temper	Reported Properties
Pole, Arm, Extrusions	ASTM B221	6061-T6	Alloy, Temper, Thickness, Tensile Strength
		6063-T6	
Pedestal, Posts	ASTM B429	6061-T6	
Bars, Plates, Stiffeners, Backing Ring, Shims, Shapes	ASTM B221	6063-T6 6061-T6	
	ASTM B209	6061-T6	
	ASTM B308		
Railing	ASTM B221	6351-T5	
		6061-T6	
	ASTM B241		
	ASTM B210		
	ASTM B429		
J-Arm Tube	ASTM B429	6061-T6	
	ASTM B221		
J-Arm Connection Plate	ASTM B209	6061-T6	
Sheet	ASTM B209	6061-T6 5154-H38 5052-H38	
Structural Shapes	ASTM B308	6061-T6	

Table 965-1 Material Requirements for Aluminum Components			
Product	Test Method	Alloy/Temper	Reported Properties
	ASTM B221		
Single Column Ground Sign Sand Castings	ASTM B26	A356-T6	
	ASTM B108	A356-T61	
Washers	ASTM B221	7075-T6 2024-T4	
Button Head or Flat Head Bolts	ASTM F468	2024-T4 6061-T6	S2 Lot Testing, Alloy, Temper
Hex Nuts	ASTM F467	6061-T6 6262-T9 2024-T4	S2 Lot Testing, Alloy, Temper

965-2.1 Light Poles: Provide aluminum lighting poles in accordance with this section and Table 965-1. Weld arms and poles in the T4 condition, using the filler metal ER4043, ER4047, ER5183, ER5356, or ER5556 in accordance with AWS D1.2 Aluminum Structural welding Code. Weld to castings in accordance with 965-2.3. Heat treat the arm and pole, until aged to the T6 condition. Transverse welds are only allowed at the base. Equip poles with a vibration damper, when specified in the contract documents.

Provide exterior surface with a clean, uniform silvery appearance, free of dark streaks and discoloration. Finish the pole and arm with a satin rubbed finish.

965-2.2 Overhead Sign Components: Provide aluminum toll gantry J-arms in accordance with this section and Table 965-1. Weld tube to plate connections in the T4 or T6 condition, using the filler metal ER4043, ER4047, ER5183, ER5356, or ER5556 in accordance with AWS D1.2 Aluminum Structural welding Code. Heat treat tube and plate in the T4 condition until aged to the T6 condition.

Provide exterior surface with a clean, uniform silvery appearance, free of dark streaks and discoloration.

965-2.3 Castings: Provide aluminum castings in accordance with this section and Table 965-1. Weld aluminum castings to itself or aluminum tube to castings using the filler metal ER4043, in accordance with AWS D1.2 Aluminum Structural welding Code. Heat treat the castings, until aged to the T6 condition.

965-2.4 Railing: Provide aluminum railing in accordance with this section and Table 965-1. Weld aluminum railing using the filler metal ER4043, ER4047, ER5183, ER5356, or ER5556 in accordance with AWS D1.2 Aluminum Structural welding Code.

965-2.5 Static Sign Assemblies: Provide aluminum sheet, plate, and structural shapes in accordance with this section and Table 965-1. Weld structural profiles to itself or aluminum components using ER4043, ER4047, ER5183, ER5356 or ER5556 in accordance with AWS D1.2 Aluminum Structural Welding Code. Heat treat the structural profiles, until aged to the T6 condition.

965-2.6 Transformer Bases (Excluding Lighting):

965-2.6.1 Product Acceptance: Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation, showing that the product meets the applicable requirements.

Table 965-2 Submittal Compliance Requirements	
Documentation	Requirements
Certified Test Report	Shows that product meets Moment Capacity
Installation Instructions	Include installation instructions
Product Identification Photo	Display's the manufacturer's name or logo and the model number.
Product Photo	Displays the significant features of the product as required in this section.
Technical Data Sheet or Product Drawing	Uniquely identifies the product and includes product details, notes, material specifications, dimensions, and sizes meeting the specification

965-2.6.2 Physical Requirements: Meet the requirements of Table 965-3.

Table 965-3 Physical Requirements for Transformer Base		
Feature	Requirement	Documentation
Height	Base is 12 to 18 inches in height	Technical Data Sheet or Product Drawing
Base Material	ASTM B26, 356 T6 or 319	Technical Data Sheet or Product Drawing
Threaded Hub	Hub located at the top for mounting a nominal 4-inch Schedule 40 (4-1/2-inch outside diameter) aluminum pole. The threaded hub must be tapped to allow full pole engagement.	Technical Data Sheet or Product Drawing
Fastening	Provides for fastening to a foundation with four 3/4-inch anchor bolts located 90 degrees apart. The base design must allow for bolts that are placed off-center.	Technical Data Sheet or Product Drawing
Door Size	Provides a door opening of not less than 8 inches by 8 inches.	Technical Data Sheet or Product Drawing
Door Material	The door must be constructed of fiberglass or other non-combustible, non-aluminum material.	Technical Data Sheet or Product Drawing
Door Attachment	Attach the door to the base with cleats and one stainless steel socket button head screw or by other means suitable for NEMA 3 electrical enclosures.	Technical Data Sheet or Product Drawing
Moment Capacity	Supports an ultimate moment capacity of 10,000 foot-pounds, without breaking, cracking or rupturing in any manner.	Certified Test Report
Breakaway	Meets the requirements in the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.	FHWA Eligibility Letter.

965-3 Paint for Poles, Pedestals, and Posts.

Paint systems used on aluminum poles, pedestals, and posts shall meet the color requirements as specified in the Contract Documents. All paint systems shall possess physical properties and handling characteristics that are compatible with the application requirements of Section 646. Materials shall be specifically intended for use over aluminum. Paint systems shall exhibit no loss of adhesion or total color difference (ΔE^*_{ab}) greater than 8.0 units for five years after final acceptance as specified in 5-11. An aluminum pole, pedestal, post, or sign panel that exhibits a cumulative surface area of delamination in excess of 50 square inches will constitute an adhesion failure. Delamination shall be defined as any area of exposed metal surface subsequent to hand tool cleaning. A ΔE^*_{ab} value exceeding 8.0 units per the International Commission on Illumination L*a*b* 1976 (CIELAB) space and color difference formula, measured in accordance with ASTM D2244, will constitute a color retention failure.

The Department will measure and enter in the Department's database the CIELAB color chromaticity coordinates for the color of the top coat of sample coupons provided as required by 646-2.7 using a BYK-Gardner Handicolor colorimeter using D65 illuminant and 2-degree geometry settings. The Department-measured CIELAB chromaticity coordinates shall define the initial color and will be used for resolution of color retention failures and the resolution of color retention disputes.

965-4 Certification.

Produce a certificate of compliance for non-APL products, upon request of the Engineer. Certificates of compliance shall identify the reportable properties of Table 965-1.

SECTION 967
COMPONENTS FOR GUARDRAIL

967-1 General.

This Section covers the material and fabrication requirements for guardrail components. All timber and steel components supplied under this Specification shall be from producers currently on the Department's Production Facility Listing. Producers seeking inclusion on the Department's Production Facility Listing must meet the requirements of Section 105.

967-2 Timber Posts and Timber Offset Blocks.

Timber products must have a minimum stress grade of 1200 psi and meet the material requirements of Section 954. Timber is to be dressed on four sides (S4S) and treated in accordance with the post requirements in Section 955. Timber posts and offset blocks shall be shaped and drilled prior to wood treatment. Posts shall not vary more than 1 inch and offset blocks shall not vary more than 0.25 inches from the specified dimensions shown in the Standard Plans.

967-3 Steel Components.

Steel materials must meet the requirements of Table 967-1 below.

Production facilities must submit certified mill analyses to the Department for review and approval. Certified mill analyses must be signed by a quality control representative, describe each LOT of components, and show compliance with Table 967-1.

All steel components must be melted and manufactured in the United States. The certified mill analysis must show that the included material meets the Buy America, Source of Supply-Steel requirements in Section 6.

Where specified, components must be welded in accordance with the American Welding Society Structural Welding Code ANSI/AWS D1.1 using material conforming to E60XX. Nondestructive testing of welds is not required.

Table 967-1
Material Requirements for Steel Guardrail Components

Product	Standard	Grade / Type	Style	Reportable Properties
Steel Panels	AASHTO M 180	Type 2 Class A (12 Ga.) Class B (10 Ga.)	W-Beam	Heat, Yield, Tensile, Elongation, Class, Type
			Thrie-Beam	
			Thrie-Beam Transition	
End Pieces	AASHTO M 180	Type 2 Class A (12 Ga.) Class B (10 Ga.)	All	Yield, Tensile, Class, Type
Steel Posts & Offset Blocks	ASTM A36	36	All	Killed, Yield, Tensile, Elongation
	ASTM A992	50	All	

Table 967-1 Material Requirements for Steel Guardrail Components				
Rub Rail	AASHTO M 180	Type 2 Class B (10 Ga.)	All	Heat, Yield, Tensile, Elongation, Class, Type
Pipe Rail	ASTM A53	A, B	E, S	Grade, Finish
Steel Tube Foundations	ASTM A500	B	Round, Shaped	Composition, Yield, Tensile, Elongation
Brackets & Fixtures	ASTM A36	36	All	Killed, Yield, Tensile, Elongation
Bolts	ASTM A307	A, B	Button-Head	Size, Composition, Hardness, Tensile
			Hex	
			Heavy-Hex	
Nuts	ASTM A563	A, B, C, C3, D, DH, DH3	Heavy Hex	Size, Composition, Proof Load, Hardness
Washers	ASTM F436	1, 3	Circular, Beveled, Clipped, Extra Thick	Size, Hardness

967-3.1 Steel Posts, Special Steel Posts, Steel Offset Blocks, and Rub Rail: Posts must be fabricated from rolled sections with cross-sections defined in the American Institute of Steel Construction (AISC) Manual of Steel Construction. Complete all fabrication prior to galvanizing. Galvanizing shall have the composition that meets or exceeds "Prime Western Grade" in accordance with ASTM B6. Posts shall not vary more than 1 inch and offset blocks shall not vary more than 0.25 inches from the specified dimensions shown in the Standard Plans.

967-3.2 Steel Panels and End Pieces: W-beam, thrie-beam, and thrie-beam transitions must meet the requirements of Table 967-1 for steel panels. Terminal connectors, end shoes, end units, and all other compatible components must meet the requirements of Table 967-1 for end pieces.

Galvanize shall have a composition that meets or exceeds "Prime Western Grade" in accordance with ASTM B6. Type II zinc coating is required on all panels.

All w-beam and thrie-beam panels (with the exception of transition panels) must be marked by a pressed stamp showing production LOT information (e.g., AASHTO-approved brand registration, LOT number, production date, operator, etc.). Upon approval of the certified mill analysis by the Department, each LOT will be stored in the Department's database with a reference to the stamped information.

967-3.3 Bolts, Nuts, Washers, and Steel Plates: Galvanize hardware in accordance with ASTM A153. Galvanize steel plates in accordance with ASTM A153.

967-3.4 Pipe Rail: Pipe is to be Schedule 40. If applicable, weld prior to galvanizing.

967-3.5 Steel Tube Foundations: Galvanize steel tube foundations, brackets, and fixtures after all punching, drilling, stamping, and welding is complete. Galvanize in accordance with ASTM A123.

967-4 Barrier Delineators.

Barrier delineators must meet the requirements of Sections 705 and 993 and be listed on the APL.

967-5 End Delineators.

Retroreflective sheeting is to be yellow, Type IV or greater in accordance with Section 994 and listed on the APL.

967-6 Approved Products List.

967-6.1 Approach Terminal Assemblies: Approach terminals must be listed on the APL. Manufacturers seeking evaluation of their product for approval must submit:

1. A completed application in accordance with Section 6, including product drawings meeting the dimensions of Standard Plans, Index 536-001 and that is signed and sealed by a registered Florida P.E.
2. Independent test reports indicating that the product meets all crash test requirements of MASH.

967-6.2 Composite Offset Blocks: Composite offset blocks must be listed on the APL. Manufacturers seeking evaluation of their product for approval must submit an application in accordance with Section 6 and include the following:

1. Test reports from an independent laboratory showing the product meets all crash test requirements of MASH.
2. Test reports from an independent laboratory showing the composite material meets the following physical requirements:

Table 967-2		
Composite Block	Test Method	Requirement
Durometer Hardness	ASTM D2240 Shore D	Minimum 50
Durometer Hardness after UV exposure	ASTM D5870	< 15 points change from initial after exposure per ASTM D4329, 1000 hours, cycle C, type UVB-313 lamps

SECTION 970
MATERIALS FOR RAISED PAVEMENT MARKERS AND ADHESIVE

970-1 Raised Pavement Markers (RPMs).

Manufacturers seeking evaluation of their product for the Approved Product List (APL) must submit an application in accordance with Section 6 and provide documentation showing the product is in conformance with this section.

RPMs shall be classified in accordance with the following chart:

Table 970-1
RPM Class

Class	Description	Usage	Expected Normal Service	ASTM D4280 Surface Designation
B	Retroreflective	Temporary/Permanent	Long life	H, hard abrasion-resistant lens
D	Retroreflective	Temporary	One month	None
F	Internally Illuminated	Permanent	Long life	H, hard abrasion-resistant lens

970-2 Performance Requirements.

970-2.1 Class B RPMs: The RPMs shall meet the performance requirements specified in ASTM D4280, Section 6.2, for luminous intensity, flexural strength, compressive strength, resistance to cracking, and thermal cycling, as modified herein.

Submit product photo, product data sheet, and documentation from AASHTO Product Evaluation & Audit Solutions showing that the RPMs meet the requirements of this Section.

970-2.1.1 Composition: The RPM shall consist of materials conforming to ASTM D4280.

970-2.1.2 Physical Requirements: The physical size of the RPM shall conform to the requirements of ASTM D4280

The minimum area of each retroreflective face shall be 2.5 square inches. The minimum base size shall be 12 square inches.

970-2.1.3 Abrasion Resistant: Meet the coefficient of luminous intensity requirements of ASTM D4280 after abrasion.

970-2.1.4 In-Service Minimum Retroreflective Intensity: Class B RPMs shall retain a minimum coefficient of luminous intensity for 18 months of not less than 30% of the values shown in Table 1 of ASTM D4280, and a minimum luminous intensity of 0.2 cd/fc at the end of two years.

970-2.2 Class D RPMs: Submit product photo, product data sheet, and certified test reports from an independent laboratory showing that the RPMs meet the requirements of this Section.

970-2.2.1 Body Requirements: Provide RPMs made of nonferrous material. RPM dimensions are based on an x and y axis where the y dimension is parallel to the centerline and the x axis is 90° to the y axis.

The base must be approximately 4 inches along the x axis and approximately 1 inch along the y axis (L-shaped).

The vertical wall must be a minimum of 4 inches long with a minimum height of 2 inches and a maximum height of 3 inches with retroreflective sheeting affixed to the upper portion of the vertical wall. The retroreflective sheeting must be a minimum of 0.25 inch in width and extend the full length of the vertical wall.

970-2.2.2 Color Requirements: The color of the body and the retroreflective strips must be yellow.

970-2.2.3 Flexibility and Deformation Resistance: The vertical wall of the tabs must be flexible to bend under normal traffic and resistant to permanent deformation for a minimum of one month.

970-2.2.4 Adhesion: Provide tabs that adhere to the pavement such that no tab dislodges.

970-2.2.5 Retroreflective Sheeting: Use a retroreflective sheeting meeting Type IV or greater and listed on the Department's Approved Product List (APL).

970-2.2.6 Removability: Ensure the entire RPM is removable without damaging the asphalt surface.

970-2.3 Class F RPMs: Submit product photo, product data sheet, and certified test reports from an independent laboratory showing that the RPMs meet the requirements of this Section.

970-2.3.1 Functional Requirements: RPMs must be steadily-illuminated.

970-2.3.2 Electrical Requirements: Electrical power for the RPM must be provided by solar power.

RPMs must meet the performance requirements for at least 16 hours of continuous duty without sunlight. Charging time must be less than 3 hours during sunny conditions and less than 8 hours during cloudy conditions. Operation must be controlled by a photoreceptor located inside the RPM.

970-2.3.3 Physical Requirements: RPMs must have a maximum width of eight inches. The depth of embedment of the RPM housing into pavement must be 2.5 inches or less, and the housing must project 0.75 inches or less above the pavement surface.

RPMs must have a compressive strength of 20,000 pounds.

RPMs must have an IP 68 rating.

970-2.3.4 Performance Requirements: The light source for RPMs must be light-emitting diodes (LEDs).

The light produced by the RPM must only be visible from the direction of traffic that it is intended to guide. No light produced by the RPM should be visible when viewed from a height of 3.5 feet above the pavement at a distance of 20 feet from the opposite quadrant or side quadrants of the RPM's LED projection quadrant.

RPMs must be capable of producing the following luminance values when measured at the LED source:

Table 970-2 RPM Color and Luminance	
Color	Luminance (Foot-candle)
White	5.00
Yellow	1.00
Red	1.50
Blue	0.10

The RPM lenses must meet the abrasion-resistant requirements of ASTM D4280. After abrading the RPM, the luminance produced by the RPM must be 50% or greater than the values in the above table.

970-2.3.5 Warranty: The manufacturer must provide a five-year, non-prorated warranty on all components for five years from the date of final acceptance in accordance with Section 706.

970-3 Adhesive for Class B and F Raised Pavement Markers.

970-3.1 General: Adhesive as recommended by the RPM manufacturer shall be used for bonding the RPM to the pavement. Manufacturers seeking evaluation of their product for the APL must submit an application in accordance with Section 6 and provide documentation showing the product is in conformance with this Section.

970-3.2 Specific Requirements for Bituminous Adhesives: The bituminous adhesive shall meet the properties of adhesives per ASTM D4280 Section A1, including filler-free and filler alone properties. Manufacturers seeking evaluation of bituminous adhesive products shall submit field test data from the AASHTO Product Evaluation & Audit Solutions. The adhesive shall retain a minimum of 80% of RPMs at 18 months. Manufacturer to specify the recommended thickness of adhesive.

970-3.3 Specific Requirements for Epoxy Adhesives: The epoxy adhesive shall conform to the following requirements of AASHTO M 237 for Types I and II (Table 970-3).

Table 970-3					
		Type I		Type II	
Property	Test Method	Min.	Max.	Min.	Max.
Viscosity: Component A (Resin) TD Spindle at 5 rev/min, poises	AASHTO T 237	3,500	5,000	1,000	3,000
Viscosity: Component B (Hardener) TD Spindle at 5 rev/min, poises		3,500	5,000	1,000	3,000
Shear Ratio (Each Component)		2.0		2.0	
Gel Time, Minutes	AASHTO T 237	6	10	6	10
Bond Strength to Concrete, max. time, minutes to reach 200 psi	AASHTO T 237		35		210
Density lbs/gal. Component A (Resin)	AASHTO T 237	11.7	12.2	10.6	10.9
Component B (Hardener)		11.7	12.2	11.3	11.6
Slant Shear Strength (Dry) 24 hr, psi	AASHTO T 237	1,000		2,000	
Slant Shear Strength (Wet) 24 hr, psi		800		1,500	

970-4 Packaging and Labeling.

970-4.1 Raised Pavement Markers: Shipment shall be made in containers which are acceptable to common carriers and packaged in a manner which ensures delivery in perfect condition. Each package shall be clearly marked with the APL number, name of the manufacturer, type, color, quantity enclosed and date of manufacture. Show the designation of the Class B marker in accordance with ASTM D4280.

970-4.2 Adhesives: Each package shall be clearly marked with the product name, name of the manufacturer, LOT number, adhesive type, quantity enclosed, and date of manufacture.

970-5 Product Acceptance on the Project.

Acceptance will be made in accordance with the requirements of Sections 102 and 706.

SECTION 971
PAVEMENT MARKING MATERIALS

971-1 General Requirements.

971-1.1 Packaging and Labeling: The name and address of the manufacturer shall be shown on the label. The label must also show the color, date of manufacturer, lot number and APL number. The label shall warn the user of any special handling or precautions of the material, as recommended by the manufacturer. Any packaging and labeling not so marked will not be accepted.

971-1.2 Storage: All materials must have a container storage life of one year from date of manufacture. Any pavement marking materials, which although inspected and approved at the point of manufacture, hardens or livers in the containers will be rejected even though it conforms to these Specifications in all other respects.

971-1.3 Mixing: All paints shall be delivered to the project completely mixed, and ready to be used without additional oil or thinner. Thinners shall not be used under any circumstances.

971-1.4 Approved Product List (APL): All pavement marking materials shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6 and include the documentation identified in the Table 971-1.

Table 971-1

Documentation	Requirements
Product Photo	Displays the significant features of the product.
Technical Data Sheet	Uniquely identifies the product and includes product specifications, storage instructions, and recommended installation materials and equipment as applicable. Include the following information as applicable: 1. Use on concrete surfaces 2. Use on asphalt surfaces (dense graded, open graded, HFST, etc) 3. Primers or sealers, friction elements, glass spheres, retroreflective elements
Product Label	For each component of the product system. Label shall meet the requirements in 971-1.1.
Safety Data Sheet (SDS)	Pavement marking materials shall be characterized as non-hazardous as defined by Resource Conservation and Recovery Act (RCRA) 40 CFR 261. Provide supporting independent analytical data or product material safety data sheets (SDS) identifying any components listed in Table 1 of 40 CFR 261.24.
AASHTO Product Evaluation & Audit Solutions Field Test Report	For standard paint, durable paint, two reactive component material, and permanent tape, manufacturers shall provide AASHTO Product Evaluation & Audit Solutions field test data meeting FDOT Specification requirements.

Independent Laboratory Test Report	Submit independent laboratory test results meeting the requirements in 971.
Installation Instructions	Surface preparation and installation procedures for different substrates. Include the following information as applicable: 1. Sealer/primer application instructions when required 2. Application thickness 3. Application rates of glass spheres/retroreflective elements/ friction elements
Product Sample	Submit upon request from the Department. If the product is a system, a sample of each component must be submitted.

The Department will test hot-applied standard thermoplastic and profiled thermoplastic pavement marking materials in accordance with FM 5-541, Part B. The Department will test preformed thermoplastic and hot-applied high friction thermoplastic pavement marking materials in accordance with FM 5-622, Part A. A notation of the number of coats and the thickness of each coat at which the product passes testing may be placed on the APL. When listed, this will be the minimum criteria for application of the pavement marking material.

971-1.5 Samples: Field samples will be obtained in accordance with the Department's Sampling, Testing and Reporting Guide Schedule.

971-1.6 Color: Pavement markings shall meet color requirements when tested according to ASTM E2367 and E1349. Materials other than yellow shall meet the color requirements as identified in 23 CFR 665 Table 5 Appendix to Part 655, Subpart F.

Yellow materials for pavement markings shall meet the following performance requirements. The initial daytime chromaticity for yellow materials shall fall within the box created by the following coordinates:

Table 971-2				
Initial Daytime Chromaticity Coordinates (Corner Points)				
	1	2	3	4
x	0.530	0.510	0.455	0.472
y	0.456	0.485	0.444	0.400

The nighttime chromaticity for yellow materials shall fall within the box created by the following coordinates:

Table 971-3				
Nighttime Chromaticity Coordinates (Corner Points)				
	1	2	3	4
x	0.575	0.508	0.473	0.510
y	0.425	0.415	0.453	0.490

971-1.7 Additional Requirements:

Retroreflective elements shall contain no more than 200 ppm by weight of lead or arsenic when tested in accordance with the Environmental Protection Agency (EPA) Testing Methods 3052, 6010B, and 6010C.

971-2 Glass Spheres.

971-2.1 General Requirements: Glass spheres shall be of a composition designed to be highly resistant to traffic wear and to the effects of weathering for the production of a retroreflective surface, without altering day visibility of the marking. The general requirements of 971-1 apply to glass spheres.

971-2.2 Specific Properties: The large (Type 3 or larger) glass spheres used for drop on beads shall have an adhesion coating. Type 1 glass spheres used for drop on beads shall have a dual coating. Glass spheres used in the intermix of materials are not required to be coated.

The following physical requirements apply:

Table 971-4

Property	Test Method	Specification
Roundness*	AASHTO R 98	Min: 70% by weight
Roundness**	AASHTO R 98	Min: 80% by weight
Refractive Index*	ASTM C1648 -Becke Line Method (25+/-5C)	1.5 minimum
Refractive Index**	ASTM C1648 -Becke Line Method (25+/-5C)	1.9 minimum

*Type 1, 3, 4 and 5 beads
**High Index beads

Table 971-5

Sieve Size	Percent by Mass Passing Designated Sieve (AASHTO R 98) Grading Designation				
	Type 1*	Type 3*	Type 4*	Type 5*	High Index**
No. 8				100	
No. 10			100	95 - 100	
No. 12		100	95 - 100	80 - 95	
No. 14		95 - 100	80 - 95	10 - 40	
No. 16	100	80 - 95	10 - 40	0 - 5	100
No. 18		10 - 40	0 - 5	0 - 2	
No. 20	95 - 100	0 - 5	0 - 2		95 - 100
No. 25		0 - 2			
No. 30	75 - 95				55 - 75
No. 40					15 - 35
No. 50	15 - 35				0 - 5
No. 80					
No. 100	0 - 5				

*AASHTO M247
** Federal Specification TT-B-1325D17

971-2.3 Sampling: A random 50-pound sample of glass spheres shall be obtained for each 50,000 pounds shipped. Send each 50-pound sample to the State Materials Office.

971-2.4 Containers: The spheres shall be furnished in new 50-pound moisture-proof bags or 2,000-pound triwall boxes. All containers shall meet Interstate Commerce Commission requirements for strength and type.

971-3 Standard Paint.

971-3.1 General: Standard paints shall include water reducible products that are single packaged and ready mixed. The paint shall have the capability of being cleaned and flushed from the pavement marking machines using regular tap water and any required rust inhibitors. The manufacturer shall have the option of formulating the paint according to his own specifications. However, the requirements delineated in this Specification and Section 710 shall apply regardless of the type of formulation used. The paint shall be free from all skins, dirt, and foreign objects.

971-3.2 Composition:

Table 971-6		
Component	Test Method	Criteria
Total Solids, by weight	ASTM D2369	minimum 75%
Pigments, by weight	ASTM D3723	minimum 57%
Vehicle Solids % of Vehicle*		minimum 40%
TiO_2, Type II Rutile (white paint only)	ASTM D476	minimum 1.0 lb/gal
Volatile Organic Compound, (VOC)	ASTM D3960	maximum 150 g/L
*Vehicle Solids % of Vehicle = $\frac{(\%\ \text{total solids} - \%\ \text{pigment})}{(100 - \%\ \text{pigment})}$		

971-3.3 Physical Requirements:

Table 971-7			
Property	Test Method	Minimum	Maximum
Density	ASTM D1475	13.5 ± 1.4 lb/gal	-
Viscosity at 77ºF	ASTM D562	80 KU	100 KU
Fineness of Grind	ASTM D1210	3(HS)	
Dry Opacity at 5 mils WFT	ASTM D2805	0.92	-
Bleed Ratio	ASTM D868	0.95	-
Flexibility	ASTM D522 Method B	Pass	-
Abrasion Resistance	ASTM D4060	Pass	-

971-3.3.1 Set To Bear Traffic Time: The paint shall set to bear traffic in not more than two minutes.

971-3.3.2 Abrasion Resistance: Test four samples using a Taber Abrader. The paint shall be applied to specimen plates using a drawdown blade having a clearance of 20 mils. Clean with a soft brush and weigh each sample. Abrade samples for 1,000 cycles with a combined load of 500 g (arm plus auxiliary weight) on each arm and CS-10 wheels. Clean the samples with a soft brush and weigh again. The average weight loss for the four plates shall not exceed 75 mg per plate.

971-3.3.3 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 300 mcd/m^2/lx and 250 mcd/m^2/lx, respectively. Black pavement markings shall have a retroreflectance of less than 20 mcd/m^2/lx. The retroreflectance of the white and yellow pavement markings at the end of the six-month period shall not be less than 150 mcd/m^2/lx.

971-3.4 Application Properties: Meet the requirements of Section 710 for application properties.

971-3.5 Packaging and Labeling: The paint shall be placed in 55 gallon open-end steel drums with a re-usable multi-seal sponge gasket or 275 gallon Intermediate Bulk Container (IBC). No more than 50 gallons of paint shall be placed in any drum or 250 gallons in any IBC to allow for expansion during transport and storage. Clearly mark the containers with the weight in pounds per gallon, the volume of materials in units of gallons.

971-4 Durable Paint.

971-4.1 General: Durable paints shall include water reducible products that are single packaged and ready mixed. The paint shall have the capability of being cleaned and flushed from the pavement marking machines using regular tap water and any required rust inhibitors. The manufacturer shall have the option of formulating the material according to his own specifications. However, the requirements delineated in this Specification and Section 710 shall apply regardless of the type of formulation used. The paint shall be free from all skins, dirt and foreign objects. The manufacturer shall provide the recommended thickness prior to installation.

971-4.2 Composition:

Table 971-8

Component	Test Method	Criteria
Total Solids, by weight	ASTM D2369	75% minimum
Pigments, by weight	ASTM D3723	57% minimum
Vehicle Solids, % on Vehicle*	-	40% minimum
TiO_2, Type II Rutile (white paint only)	ASTM D476	1.0 lb/gal minimum
Volatile Organic Compound, (VOC)	ASTM D3960	150 g/L maximum

*Vehicle Solids % of Vehicle = $\frac{(\%\text{ total solids} - \%\text{ pigment})}{(100 - \%\text{ pigment})}$

Vehicle solids shall be 100% acrylic emulsion polymer.

971-4.3 Physical Requirements:

Table 971-9			
Property	Test Method	Minimum	Maximum
Density	ASTM D1475	13.5 ± 1.4 lb/gal	N/A
Viscosity at 77ºF	ASTM D562	80 KU	100 KU
Fineness of Grind	ASTM D1210	3(HS)	-
Dry Opacity at 5 mils WFT	ASTM D2805	0.92	-
Bleed Ratio	ASTM D868	0.95	-
Flexibility	ASTM D522 Method B	Pass	-
Abrasion Resistance	ASTM D4060	Pass	-

971-4.3.1 Set to Bear Traffic Time: The paint shall set to bear traffic in not more than ten minutes.

971-4.3.2 Abrasion Resistance: Test four samples using a Taber Abrader. The paint shall be applied to specimen plates using a drawdown blade having a clearance of 20 mils. Air dry each sample until fully cured based on the manufacturer's product recommendation. Clean with a soft brush and weigh each sample. Abrade samples for 1,000 cycles with a combined load of 500 g (arm plus auxiliary weight) on each arm and CS-10 wheels. Clean the samples with a soft brush and weigh again. The average weight loss for the four plates shall not exceed 75 mg per plate.

971-4.3.3 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 450 mcd/m^2/lx and 300 mcd/m^2/lx, respectively. The retroreflectance of the white and yellow pavement markings at the end of the 18 month period shall not be less than 150 mcd/m^2/lx.

971-4.4 Application Properties: Application properties shall meet the requirements of Section 710.

971-4.5 Packaging and Labeling: The paint shall be placed in 55 gallon open-end steel drums with a re-usable multi-seal sponge gasket or 275 gallon Intermediate Bulk Container (IBC). No more than 50 gallons of paint shall be placed in any drum or 250 gallons in any IBC to allow for expansion during transport and storage. Clearly mark the containers with the weight in pounds per gallon, the volume of materials in units of gallons.

971-5 Hot-Applied Standard Thermoplastic Material.

971-5.1 General: The manufacturer shall utilize alkyd based materials only and shall have the option of formulating the material according to his own specifications. However, the requirements delineated in this Specification and Section 711 shall apply regardless of the type of formulation used. The pigment, glass spheres, and filler shall be well dispersed in the resin.

971-5.2 Composition:

Table 971-10			
Component	Test Method	White	Yellow
Binder	ASTM D4797	20% minimum	20% minimum
TiO_2, Type II Rutile	ASTM D476	10% minimum	-
Glass Spheres	ASTM D4797	40% minimum	40% minimum
Yellow Pigment		-	% minimum per manufacturer
Calcium Carbonate and Inert Filler (-200 mesh sieve)		30% maximum	37% maximum
Percentages are by weight.			

The alkyd/maleic binder must consist of a mixture of synthetic resins (at least one synthetic resin must be solid at room temperature) and high boiling point plasticizers. At least one-half of the binder composition must be 100% maleic-modified glycerol of rosin and be no less than 15% by weight of the entire material formulation.

971-5.3 Glass Spheres: The glass spheres in the intermix shall consist of 50% Type 1 and 50% Type 3 and meeting the requirements of this Section.

971-5.4 Sharp Silica Sand: Sharp silica sand shall meet the following gradation requirements:

Table 971-11	
Sieve Size	Percent by Mass Passing Designated Sieve (ASTM D1214)
20	100
50	0 to 10

971-5.5 Physical Requirements:

Table 971-12			
Property	Test Method	Minimum	Maximum
Water Absorption	ASTM D570	-	0.5%
Softening Point	ASTM D36	195ºF	-
Low Temperature Stress Resistance	AASHTO T 250	Pass	-
Specific Gravity	AASHTO T 250	1.9	2.3
Indentation Resistance	ASTM D7735* Type A Durometer	40	75
Impact Resistance	AASHTO T 250,	1.0 N·m	-
Flash Point	AASHTO T 250	475ºF	-
* The durometer and panel shall be at 115ºF with a 1,000 g load applied. Instrument measurement shall be taken after 15 seconds.			

971-5.5.1 Set to Bear Traffic Time: The thermoplastic shall set to bear traffic in not more than two minutes.

971-5.5.2 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 450 mcd/m^2/lx and not less than 350 mcd/m^2/lx,

respectively. The retroreflectance of the white and yellow pavement markings at the end of the three-year APL testing period shall not be less than 250 mcd/m^2/lx.

971-5.6 Application Properties: Application properties shall meet the requirements of Section 711.

971-5.7 Packing and Labeling: The thermoplastic material shall be packaged in suitable biodegradable or thermo-degradable containers which will not adhere to the product during shipment and storage. The container of thermoplastic material shall weigh approximately 50 pounds. The label shall also warn the user that the material shall be heated in the range as recommended by the manufacturer.

971-6 Preformed Thermoplastic Material.

971-6.1 General: The manufacturer shall have the option of formulating the material according to his own specifications. However, the requirements delineated in this Specification and Section 711 shall apply regardless of the type of formulation used. The pigment, friction elements, glass spheres, and filler shall be well dispersed in the resin.

971-6.2 Composition: The preformed thermoplastic shall consist of high quality materials, pigments, friction elements, and glass spheres or other retroreflective material uniformly distributed throughout their cross-sectional area, with a retroreflective layer of spheres or other retroreflective material embedded in the top surface.

971-6.3 Color: Materials shall meet the performance requirements specified in 971--1.6 and the following additional requirements. The initial luminance factor, Cap Y, for white preformed shall not be less than 55.

971-6.4 Physical Requirements:

Table 971-13

Property	Test Method	Minimum	Maximum
Softening Point	ASTM D36	195ºF	-
Low Temperature Stress Resistance	AASHTO T 250	Pass	-
Indentation Resistance	ASTM D7735* Type A Durometer	40	75
Impact Resistance	ASTM D256, Method A**	1.0 N·m	-

*The durometer and panel shall be at 115ºF with a 1,000 g load applied. Instrument measurement shall be taken after 15 seconds.
**The test specimen for ASTM D256 shall be 1 in. x 1 in. x 6 in. and shall not be notched.

971-6.4.1 Retroreflectivity: The white pavement markings shall attain an initial retroreflectance of not less than 200 mcd/m^2/lx. Black pavement markings shall have a retroreflectance of less than 20 mcd/m^2/lx. The retroreflectance of the white pavement markings at the end of the three-year period shall not be less than 150 mcd/m^2/lx.

971-6.4.2 Friction Resistance: Initial performance of pavement markings shall provide a minimum Dynamic Friction Tester (DFT40) value of 45 or greater in accordance with FM 5-622 – Part A. In-service pavement markings shall maintain a DFT40 value of 40 or greater for a three-year period as tested per FM 5-622,Part B.

971-6.5 Application Properties: Application properties shall meet the requirements of Section 711.

971-6.6 Packing and Labeling: The thermoplastic material shall be packaged in suitable biodegradable or thermo-degradable containers which will not adhere to the product during

shipment and storage. Clearly mark each container with the thickness of the preformed material in units of inches.

971-7 Permanent Tape Materials.

971-7.1 General: The materials for permanent tape pavement markings shall consist of white or yellow weather-resistant retroreflective film as specified herein. The pigment, glass spheres, and filler shall be well dispersed in the resin. However, the requirements delineated in this Specification and Section 713 shall apply.

971-7.2 Composition: Permanent tape pavement markings shall consist of high-quality plastic materials, pigments, and glass spheres uniformly distributed throughout their cross-sectional area, with a retroreflective layer of spheres embedded in the top surface.

971-7.3 Thickness: The APL will list the specified thickness of each approved product.

971-7.4 Durability and Wear Resistance: The film shall be weather resistant and, through normal wear, shall show no significant tearing, rollback or other signs of poor adhesion.

971-7.5 Conformability and Resealing: The pavement markings shall be capable of conforming to pavement contours, breaks and faults under traffic at pavement temperatures recommended by the manufacturer. The film shall be capable of use for patching worn areas of the same types of film in accordance with the manufacturer's recommendations.

971-7.6 Tensile Strength: The pavement markings shall have a minimum tensile strength of 40 psi when tested according to ASTM D638. A rectangular test specimen 6 inches by 1 inch by 0.05 inches minimum thickness shall be tested at a temperature range of 40 to 80ºF using a jaw speed of 0.25 inch/min.

971-7.7 Pigmentation: The pigment shall be selected and blended to provide a material which is white or yellow conforming to standard highway colors through the expected life of the pavement markings. Test laboratory samples in accordance with ASTM E811 and E1349.

971-7.8 Glass Spheres: The pavement markings shall have glass retention qualities such that, when at room temperature a 2 inches by 6 inches specimen is bent over a 0.5 inch diameter mandrel axis, a microscopic examination of the area on the mandrel shall show no more than 10% of the spheres with entrapment by the material of less than 40%. The bead adhesion shall be such that spheres are not easily removed when the film surface is scratched firmly with a thumbnail.

971-7.9 Retroreflectivity: The materials shall attain an initial retroreflectance of not less than 450 mcd/m^2/lx for white markings and not less than 350 mcd/m^2/lx for yellow markings. The pavement markings shall retain a minimum retroreflectance for two years of not less than 300 mcd/m^2/lx for white markings and not less than 250 mcd/m^2/lx for yellow markings. The retroreflectance of the white, yellow and contrast pavement markings at the end of the three-year period shall not be less than 150 mcd/m^2/lx.

971-7.10 Packaging and Labeling: Ship all permanent tape materials in containers which will not adhere to the product during shipment and storage. Clearly mark each container with the thickness of the preformed material in units of inches.

971-8 Two Reactive Component Material.

971-8.1 General: Two reactive component materials intended for use under this Specification shall include, but not be limited to, epoxies, polyesters and urethanes. The manufacturer shall have the option of formulating the material according to his own specifications. However, the criteria outlined in this Specification and Section 709 shall apply

regardless of the type of formulation used. The material shall be free from all skins, dirt and foreign objects.

971-8.2 Composition:

Table 971-14		
Component	Test Method	Criteria
TiO_2, Type II Rutile (white material only)	ASTM D476	minimum 10% by weight
Volatile Organic Compound, (VOC)	ASTM D3960	maximum 150 g/L

971-8.3 Physical Requirements:

Table 971-15			
Property	Test Method	Minimum	Maximum
Adhesion to Concrete	ASTM D7234	Concrete Failure	-
Hardness	ASTM D7735, Type D	75	-
Abrasion Resistance	ASTM D4060	Pass	-

971-8.3.1 Set To Bear Traffic Time: The material shall set to bear traffic in not more than two minutes.

971-8.3.2 Abrasion Resistance: Test four samples using a Taber Abrader. The material shall be applied to specimen plates using a drawdown blade having a clearance of 15 mils. Clean with a soft brush and weigh each sample. Abrade samples for 1,000 cycles with a combined load of 500 g (arm plus auxiliary weight) on each arm and CS-10 wheels. Clean the samples with a soft brush and weigh again. The average weight loss for the four plates shall not exceed 60 mg per plate.

971-8.3.3 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 450 mcd/m^2/lx and not less than 350 mcd/m^2/lx, respectively. The retroreflectance of the white and yellow pavement markings at the end of the three-year period shall not be less than 150 mcd/m^2/lx.

971-8.4 Application Properties: Application properties shall meet the requirements of Section 709.

971-8.5 Packaging and Labeling: The two reactive component material shall be placed in 55 gallon open-end steel drums with a re-usable multi-seal sponge gasket or 275 gallon Intermediate Bulk Container (IBC). No more than 50 gallons of material shall be placed in any drum or 250 gallons in any IBC to allow for expansion during transport and storage. Clearly mark the containers with the volume of materials in units of gallons and the product name.

971-9 Profiled Thermoplastic Material.

971-9.1 General: The manufacturer shall utilize alkyd based materials only and shall have the option of formulating the material according to his own specifications. However, the requirements delineated in this Specification shall apply regardless of the type of formulation used. The pigment, retroreflective elements, and filler shall be well dispersed in the resin.

971-9.2 Composition:

Table 971-16			
Component	Test Method	White	Yellow
Binder	ASTM D4797	20% minimum	20% minimum
TiO_2, Type II Rutile	ASTM D476	10% minimum	-
Retroreflective Elements	ASTM D4797	% minimum per manufacturer	% minimum per manufacturer
Yellow Pigment		-	% minimum per manufacturer
Calcium Carbonate and Inert Filler (-200 mesh sieve)		% minimum per manufacturer	% minimum per manufacturer
Note: Percentages are by weight.			

The alkyd/maleic binder must consist of a mixture of synthetic resins (at least one synthetic resin must be solid at room temperature) and high boiling point plasticizers. At least one-half of the binder composition must be 100% maleic-modified glycerol of rosin and be no less than 15% by weight of the entire material formulation.

971-9.3 Retroreflective Elements: The retroreflective elements in the intermix shall be determined by the manufacturer and identified for the APL.

971-9.4 Physical Requirements:

Table 971-17			
Property	Test Method	Minimum	Maximum
Water Absorption	ASTM D570	-	0.5%
Softening Point	AASHTO T 250	210ºF	-
Low Temperature Stress Resistance	AASHTO T 250	Pass	-
Specific Gravity	AASHTO T 250	1.9	2.3
Indentation Resistance	ASTM D7735* Type A Durometer	65	-
Impact Resistance	AASHTO T 250	1.0 N·m	-
Flash Point	AASHTO T 250	475ºF	-
*The durometer and panel shall be at 80ºF, with a 1,000 g load applied. Instrument measurement shall be taken after 15 seconds.			

971-9.4.1 Set To Bear Traffic Time: When applied at the temperatures and thickness specified by Section 701, the baseline material shall set to bear traffic in not more than two minutes. The bumps shall set to bear traffic in not more than 10 minutes at ambient air temperatures of 80ºF or less and in not more than 15 minutes for ambient air temperatures exceeding 80ºF.

971-9.4.2 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 300 mcd/m^2/lx and not less than 250 mcd/m^2/lx, respectively. The retroreflectance of the white and yellow pavement markings at the end of the three-year period shall not be less than 150 mcd/m^2/lx.

971-9.4.3 Durability: Durability shall include flattening of the profile or raised portions of the line. The flattening of the profile or raised portion of the line shall not exceed 25% at the end of the three-year period.

971-9.5 Application Properties: Application properties shall meet the requirements of Section 701.

971-9.6 Packing and Labeling: The thermoplastic material shall be packaged in suitable biodegradable or thermo-degradable containers which will not adhere to the product during shipment and storage. The container of thermoplastic material shall weigh approximately 50 pounds. The label shall warn the user that the material shall be heated in the range as recommended by the manufacturer.

SECTION 972
RECYCLED PLASTIC PRODUCTS

972-1 Description.

Recycled plastic products shall include certified test reports from an approved independent test laboratory that shows the material meets all specifications herein and the manufacturer shall certify the following:

1. The source of the recycled plastic waste, including the state (FL, GA, etc.) from which the recycled plastic was obtained, and type of waste (consumer or industrial).
2. The total percent of recycled plastic in the final product.

972-2 Definitions.

972-2.1 Recycled Plastic: Those plastics composed of post-consumer material or recovered industrial material only, or both, that may or may not have been subjected to additional processing steps designed to afford products such as regrind or reprocessed or reconstituted plastics.

972-2.2 Post-Consumer Materials: Those products generated by a business or consumer that have served their intended end use and that have since been separated or diverted from solid waste for the purpose of collection, recycling, and re-disposition.

972-2.3 Recovered Material: Materials and by-products that have been recovered or diverted from solid waste, but not including those materials and by-products generated from, and commonly used within, an original manufacturing process.

972-3 Materials.

The materials used for recycled plastic products shall consist of a minimum of 70% by weight of recycled plastic. The products shall exhibit good workmanship and shall be free of burns, discoloration, contamination, and other objectionable marks or defects which affect appearance or serviceability. Only chemicals, including fillers and colorants, designed to inhibit photo degradation, biological/biochemical decomposition, insect infestation, or burning will be permitted to enhance durability. The use of sufficient additives to inhibit photo degradation over the lifetime of the product is required.

972-4 Sampling.

One additional product per 1,000, or a minimum of one per order shall be included in the order for Department testing.

SECTION 973
FIBER REINFORCED POLYMER (FRP) COMPOSITE STRUCTURAL SHAPES

973-1 Description.

This Section covers material and fabrication requirements for fiber reinforced polymer (FRP) composite structural shapes.

973-2 Product Acceptance.

Obtain FRP composites from a producer that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

973-3 Thermoset Pultruded Structural Shapes.

Thermoset pultruded structural shapes must meet the requirements in the materials section of the ASCE, Pre-Standard for Load & Resistance Factor Design (LRFD) of Pultruded Fiber Reinforced Polymer (FRP) Structures.

Manufactured components shall be inspected according to ASTM D3917 for dimensional tolerances and ASTM D4385 for visual defects.

Pultruded profiles located on bridge and overhead sign structures shall meet a flame spread index of Class B in accordance with ASTM E84 and meet the requirements of UL94 with a rating of V-1.

973-4 Vacuum Infusion Processed (VIP) Structural Shapes.

973-4.1 Materials:

973-4.1.1 Fibers: Use commercial grade glass fibers that conform to ASTM D578. Glass fibers may be in any form such as rovings, woven fabrics, braided fabrics, stitched fabrics, continuous fiber mats, continuous strand mats, continuous filament mats (CFM), and chopped strand mats (CSM) of any size or weight.

Each structural element shall contain a minimum of 40% (by weight) of glass fibers oriented in a minimum of two directions in accordance with the manufacturer's requirements.

Tensile strength of glass fiber strands, yarns and rovings shall not be less than 290 ksi in accordance with ASTM D7290, determined by a tension test in accordance with ASTM D2343.

973-4.1.2 Resin: Use a commercial grade thermoset resin for fabricating shapes.

973-4.1.3 Additives: Additives such as fillers, promoters, accelerators, inhibitors, UV agents, and pigments, used in the processing or curing shall be compatible with the fiber and resin.

973-4.2 Physical and Mechanical Properties: The physical properties of VIP FRP products shall conform to the requirements of Table 973-1. The characteristic mechanical properties of VIP FRP composite structural members, determined in accordance with ASTM D7290, shall equal or exceed the minimum requirements in Table 973-2 for shapes and Table 973-3 for plates.

Table 973-1 Required Physical Properties - VIP FRP		
Physical Property	Requirement	Test Method
Barcol Hardness	> 40	ASTM D2583
Glass Transition Temperature	> 180 F	ASTM D4065
Coefficient of Thermal Expansion	< 7.5 x 10^{-6} in/in/ F (longitudinal)	ASTM D696
Moisture Equilibrium Content	< 2%	ASTM D570, Section 7.4

Table 973-2 Required Mechanical Properties - VIP FRP Shapes		
Property	Minimum Requirement	Test Method
Longitudinal Tensile Strength	30,000 psi	ASTM D3039
Transverse Tensile Strength	7,000 psi	
Longitudinal Tensile Modulus	3 x 10^6 psi	
Transverse Tensile Modulus	0.8 x 10^6 psi	
Longitudinal Compressive Strength	30,000 psi	ASTM D6641
Longitudinal Compressive Modulus	3 x 10^6 psi	
Transverse Compressive Modulus	1 x 10^6 psi	
In-Plane Shear Strength	8,000 psi	ASTM D5379
In-Plane Shear Modulus	0.4 x 10^6 psi	ASTM D5379
Interlaminar Shear Strength	3,500 psi	ASTM D2344

Table 973-3 Required Mechanical Properties -VIP FRP Plates		
Property	Minimum Requirement	Test Method
Longitudinal Tensile Strength	20,000 psi	ASTM D3039
Transverse Tensile Strength	7,000 psi	
Longitudinal Tensile Modulus	1.8 x 10^6 psi	
Transverse Tensile Modulus	0.7 x 10^6 psi	
Longitudinal Compressive Strength	24,000 psi	ASTM D6641
Transverse Compressive Strength	15,500 psi	
Longitudinal Compressive Modulus	1.8 x 10^6 psi	
Transverse Compressive Modulus	1 x 10^6 psi	
Longitudinal Flexural Strength	30,000 psi	ASTM D790
Transverse Flexural Strength	13,000 psi	
Longitudinal Flexural Modulus	1.6 x 10^6 psi	
Transverse Flexural Modulus	0.9 x 10^6 psi	
In-Plane Shear Strength	6,000 psi	ASTM D5379
In-Plane Shear Modulus	0.4 x 10^6 psi	
Interlaminar Shear Strength	3,500 psi	ASTM D2344

973-4.3 Fire, Smoke and Toxicity: VIP profiles located on bridge and overhead sign structures shall meet a flame spread index of Class B in accordance with ASTM E84 and meet the requirements of UL94 with a rating of V-1.

973-4.4 Impact Tolerance: Where impact resistance is stipulated, impact resistance shall be determined in accordance with ASTM D7136.

973-5 Thermoplastic Structural Shapes.

973-5.1 General: For the purpose of this specification, use the following definitions:

a. Thermoplastic Structural Shapes (TSS) includes a thermoplastic matrix reinforced with chopped fiberglass filaments.

b. Reinforced Thermoplastic Structural Shapes (RTSS) includes a thermoplastic matrix reinforced with chopped fiberglass filaments and continuous FRP reinforcing bars meeting the requirements of this Section. Steel reinforcing bars are not permitted.

973-5.2 Materials: Use polyethylene made from recycled post consumer or post industrial thermoplastics. Mix the polyethylene with appropriate colorants, UV inhibitors, hindered amine light stabilizers, antioxidants, and chopped fiberglass reinforcement so that the resulting product meets the requirements specified in Table 973-4 for RTSS and Table 973-5 for TSS. Use a minimum of 15% (by weight) chopped fiberglass reinforcement for both TSS and RTSS. The thermoplastic matrix must not corrode, rot, warp, splinter or crack. Meet the requirements of 932-3 for FRP reinforcing bar materials.

For RTSS members, the use of separate materials for skin and core is at the discretion of each manufacturer; however, both materials must meet the requirements in Table 973-4. The material surrounding the rebar within 1 inch from the rebar surface shall not contain voids greater than 3/4 inch diameter and extend no further than 2 inches along the length of the member. The cross section of the product shall not contain voids exceeding 1-1/4 inches in diameter and the sum of all voids greater than 3/8 inches in diameter shall not exceed 5% of the cross sectional area.

Extrude final product as one continuous piece with no joints or splices to the dimensions and tolerances in accordance with Table 973-6.

Reject any sections containing cracks or splits.

Table 973-4
RTSS Matrix

Property	Test Method	Requirement
Density	ASTM D792	48–63 pcf
Water Absorption	ASTMD570	2 hrs: <1.0% weight increase 24 hrs: <3.0% weight increase
Brittleness	ASTM D746	Brittleness temperature < minus 40°C
Impact Resistance	ASTM D256, Method A (Izod)	>0.55 ft-lbs/in
Hardness	ASTM D2240	44-75 (Shore D)
Ultraviolet	ASTM D4329 UVA	500 hours <10% change in Shore D Durometer Hardness

Table 973-4 RTSS Matrix		
Property	Test Method	Requirement
Abrasion	ASTM D4060	Weight Loss: <0.02 oz Cycles = 10,000 Wheel = CS17 Load = 2.2 lb
Chemical Resistance	ASTM D543	Sea Water: <1.5% weight increase Gasoline: <9.5% weight increase No. 2 Diesel: <6.0% weight increase
Tensile Properties	ASTM D638	2,200 psi at break min.
Compressive Modulus	ASTM D695	40 ksi min.
Static Coefficient of Friction	ASTM D1894	0.25, wet max.
Screw Withdrawal	ASTM D6117	400 lb (screw) min.

Table 973-5 TSS Matrix		
Property	Test Method	Requirement
Density	ASTM D792	50-65 pcf
Impact Resistance	ASTM D256 Method A (Izod)	>0.55 ft-lbs/in
Hardness	ASTM D2240	44-75 (Shore D)
Ultraviolet	ASTM D4329 (UVA)	500 hours <10% change in Shore D Durometer Hardness
Chemical Resistance	ASTM D756 or ASTM D543	Sea Water: <1.5% weight increase Gasoline: <7.5% weight increase No. 2 Diesel: <6.0% weight increase
Tensile Properties	ASTM D638	3,000 psi at break min.
Static Coeffecient of Friction	ASTM D2394	0.25, wet or dry min.
Nail Withdrawal or Screw Withdrawal	ASTM D6117	250 lb (nail) min. 400 lb (screw) min.
Secant Modulus at 1% Strain	ASTM D6109	150,000 psi min.
Flexural Strength	ASTM D6109	2,500 psi min.
Compressive Strength	ASTM D6108	2,200 psi min.
Compressive Strength Perpendicular to grain	ASTM D6108	700 psi min.

Table 973-6 Tolerances	
Dimension	Tolerance
Length	0/+6 inch
Width – RTSS Width – TSS	±1/2 inch ±1/4 inch
Height – RTSS Width – TSS	±1/2 inch ±1/4 inch
Clear cover from outer surface to rebar elements (RTSS)	≥3/4 inch (wales) ±1/2 inch (other)
Straightness (while lying on a flat surface)	<1-1/2 inches per 10 feet

SECTION 974
SURFACE APPLICATIONS

974-1 Description.

This section specifies the material requirements for detectable warnings, patterned pavement and green-colored pavement markings.

974-2 Detectable Warnings.

Provide detectable warnings in accordance with the Americans with Disabilities Act Standards for Transportation Facilities, Section 705. Provide detectable warnings consisting of materials intended for exterior use subject to routine pedestrian traffic and occasional vehicular traffic. Provide detectable warnings with size and pattern comprised of truncated domes aligned in parallel rows. Detectable warnings with a diagonal pattern are not permitted. Detectable warnings consisting of truncated domes fabricated in the field are not permitted.

974-2.1 Approved Product List Submittal Requirements: Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the documentation identified in the Table 974-1. Documentation and reports must demonstrate that the product meets the requirements of this Section, Section 527, and the Standard Plans, Index 522-002.

Table 974-1

Documentation	Requirements
Product Photo	Displays the significant features of the product.
Technical Data Sheet	Uniquely identifies the product and includes product specifications, storage instructions, and recommended installation materials and equipment as applicable.
Product Label	For each component of the product system.
Safety Data Sheet (SDS)	SDS meeting OSHA requirements for product and manufacturer recommended installation materials as applicable. Non-Hazardous, per RCRA Subtitle C Table 1 of 40 CFR 261.24 “Toxicity Characteristic” and not exude fumes which are hazardous, toxic, or detrimental to persons or property.
AASHTO Product Evaluation & Audit Solutions Test Report or Independent Laboratory Test Report	Testing must be conducted using the Project Work Plan for AASHTO Product Evaluation & Audit Solutions Laboratory Testing of Detectable Warning Systems, using the cold exposure category [i.e., 4 repetitions of the following exposure series: Abrasion (4 cycles) followed by freeze-thaw (15 cycles)].
Independent Laboratory Test Report	Test CAP Y in accordance with ASTM E1349.
Installation Instructions	Surface preparation and installation procedures for different substrates. The minimum curing time prior to installing the product for surface-applied materials.

Table 974-1	
Documentation	Requirements
Product Sample	Submit upon request from the Department. If the product is a system, a sample of each component must be submitted.

974-2.2 Performance Requirements: Provide detectable warnings that meet the performance requirements of Table 974-2. Manufacturers shall provide before exposure testing and proof that the product has been submitted for exposure testing. All testing shall be complete by July 1, 2023.

<table>
<tr><td colspan="3">Table 974-2</td></tr>
<tr><td>Property</td><td>Documentation</td><td>Test Value</td></tr>
<tr><td>Domes and Spacing Dimensional Testing[1]</td><td>Provide Test Report[2] or Independent Laboratory Test Report</td><td>Meets the requirements of the Americans with Disabilities Act Standards for Transportation Facilities, Section 705.</td></tr>
<tr><td>Slip Resistance[1]</td><td>Provide Test Report[2] or Independent Laboratory Test Report</td><td>Dry Coefficient of Friction – 0.8 min.
Wet Coefficient of Friction – 0.65 min.
(include recessed areas between truncated domes).</td></tr>
<tr><td>Visual and Microscopic Evaluation[1]</td><td>Provide Test Report[2] or Independent Laboratory Test Report</td><td>No lifting, debonding, flaking, missing domes, partial domes, or significant cracking.</td></tr>
<tr><td>Bond Strength on Uncured (≤ 72 hours) Concrete Panel [AASHTO T 388]</td><td>Independent Laboratory Test Report</td><td>For surface applied detectable warning systems installed on uncured concrete:
150 psi min. with an elapsed concrete panel cure time of less than 72 hours.</td></tr>
<tr><td>Color/Contrast [1,3] [ASTM G155 / D4355]</td><td>Independent Laboratory Test Report</td><td><table><tr><td>Color</td><td>CAP Y</td></tr><tr><td>Safety Yellow</td><td>25 – 45</td></tr><tr><td>Brick Red</td><td>5 – 15</td></tr><tr><td>Black</td><td>0 – 5</td></tr></table></td></tr>
<tr><td colspan="3">[1] Report values before and after exposure testing.
[2] Test report from AASHTO Product Evaluation & Audit Solutions
[3] 1,000 hours, UV exposure only.</td></tr>
</table>

974-3 Patterned Pavement.

Provide patterned pavement products that produce an adherent, weather resistant, friction resistant, and wear resistant surface that meets the requirements of this Section, and Section 523.

Material color and friction elements shall be integral and homogenous.

Patterned pavement installations requiring removal of pavement are not permitted.

974-3.1 Approved Product List Submittal Requirements: Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the documentation identified in Table 974-3. Documentation and reports must demonstrate that the product meets the requirements of this Section and Section 523.

Table 974-3	
Documentation	Requirements
Product Photo	Displays the significant features of the product.
Technical Data Sheet	Uniquely identifies the product and includes product specifications, storage instructions, and recommended installation materials and equipment as applicable. Include the following information as applicable: 1. Use on concrete surfaces. 2. Use on asphalt surfaces. 3. Patterns, textures, and templates. 4. Resin, sealers, coatings, coloring, and friction materials. 5. Friction material source and rate of application.
Product Label	For each component of the product system.
Safety Data Sheet (SDS)	SDS meeting OSHA requirements for each material used in the product system. Non-Hazardous, per RCRA Subtitle C Table 1 of 40 CFR 261.24 "Toxicity Characteristic" and not exude fumes which are hazardous, toxic, or detrimental to persons or property.
Installation Instructions	Surface preparation and installation procedures for different substrates.
Product Sample	Submit upon request from the Department. A sample of each component must be submitted.

974-3.2 Performance Requirements: Provide patterned pavement products that meet the performance requirements of Table 974-4.

974-3.2.1 Department Testing: Submit product samples and panels for Department analysis upon request from the Department and in accordance with this Specification. Products are subject to verification testing in accordance with this Section and infrared identification curve (2.5 to 15 µm) for the vehicle component.

974-3.2.2 Friction Resistance: In-service pavement markings shall maintain a DFT40 value of 40 or greater, or FN 40R value of 35 or greater for a three-year period as tested per FM 5-622-Part B.

Table 974-4		
Property	Documentation	Test Method and Value
Wear	Field Service Test Photos	Visual, Wearing shall not expose more than 15% of the underlying surface area as measured within the traveled way for 3 years.
Initial Friction Resistance [FM 5-622 Part A]	Department Testing Reports	Dynamic Friction Tester (DFT40) ≥ 50

974-4 Green-Colored Pavement Markings.

Provide high-quality materials, producing an adherent, weather-resistant, friction-resistant, wear-resistant surface, and shall be uniformly distributed throughout the cross-sectional area. Color shall be integral and consistent throughout the installation.

974-4.1 Approved Product List Requirements: Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the documentation identified in Table 974-5. Documentation and reports must demonstrate that the product meets the requirements of this Section. Manufacturers must identify the materials for all components of the green-colored pavement marking materials system including friction materials.

Table 974-5

Documentation	Requirements
Product Photo	Displays the significant features of the product.
Technical Data Sheet	Uniquely identifies the product and includes product specifications, storage instructions, and shelf life.
Installation Instructions	Uniquely identifies the product and includes the following information as applicable: 1. Surface preparation and installation procedures for different substrates such as concrete and asphalt surfaces. 2. The minimum substrate curing time prior to installing the product. 3. Installation materials and equipment. 4. Resin, sealers, coatings, coloring, and friction materials. 5. Friction material source and rate of application. 6. Number of coats and the thickness of each coat.
Product Label	For each component of the product system. Labels must contain the following information as applicable: 1. Uniquely identifies the product name. 2. Address of the manufacturer. 3. Show the color, date of manufacture, and lot number. 4. Warning of any special handling or precautions of the material, as recommended by the manufacturer. 5. The two reactive component material shall be clearly marked with the volume of materials in units of gallons and the product name. 6. The thermoplastic material shall be clearly marked with the thickness of the preformed material in units of inches.
Product Packaging	The thermoplastic material shall be packaged in suitable biodegradable or thermo-degradable containers which will not adhere to the product during shipment and storage.

Table 974-5	
Documentation	Requirements
Safety Data Sheet (SDS)	SDS meeting OSHA requirements for each product component and manufacturer recommended installation materials as applicable. Non-Hazardous, per RCRA Subtitle C Table 1 of 40 CFR 261.24 “Toxicity Characteristic” and not exude fumes which are hazardous, toxic, or detrimental to persons or property.
Independent Laboratory Test Report	Glass elements shall contain no more than 200 ppm by weight of lead or arsenic when tested in accordance with the Environmental Protection Agency (EPA) Testing Methods 3052, 6010B, and 6010C.
Independent Laboratory Test Report	Report color and friction before polishing in accordance with FM 5-622 Part A
Product Sample for Department Testing	Submit upon request from the Department. If the product is a system, a sample of each component must be submitted.
Product Panels for Department Testing	Submit upon request from the Department. Prepare panels in accordance with FM 5-622-Part A

974-4.2 Performance Requirements: Provide colored pavement products that meet the performance requirements of Table 974-6 and Table 974-7 this Section.

974-4.2.1 Department Testing: Submit product samples and panels for Department analysis upon request from the Department and in accordance with this Specification. Products are subject to verification testing in accordance with this Section and infrared identification test.

Table 974-6		
Property	Documentation	Test Method and Value
Color	Department Testing Reports	The daytime chromaticity (x, y), both before and after polishing and accelerated weathering, must fall within the box in Table 974-7.
Daytime Luminescence Factor (Y)	Department Testing Reports	Must be greater than or equal to 15, both before and after polishing and accelerated weathering. [FM 5-622 Part A]
Wear	Department Field Service Test Photos	Visual, Wearing shall not expose more than 15% of the underlying surface area as measured within the traveled way for 3 years.
Initial Friction Resistance	Department Testing Reports	Dynamic Friction Tester (DFT40) ≥ 50 in accordance with [FM 5-622 Part A]
In-service Friction Resistance]	Department Testing Report	Dynamic Friction Test (DFT40) value of 40 or greater in accordance with [FM 5-622 Part B

974-4.2.2 Green Color Requirements:

Table 974-7				
Daytime Chromaticity Coordinates for Green-Colored Pavement Marking Materials (Corner Points)				
	1	2	3	4
x	0.230	0.266	0.367	0.444
y	0.754	0.460	0.480	0.583

974-4.2.3 Pavement Distress: Pavement distress occurring after installation of colored pavement marking materials may result in removal from the APL, and require the manufacturer to mill, resurface, replace, and install with a product on the APL at no additional cost to the Department.

SECTION 975
STRUCTURAL COATING MATERIALS

975-1 General Requirements.

975-1.1 General: Upon curing, all coatings and/or coating systems must produce an adherent coating that is visually uniform. The composition of the coating is left to the discretion of the manufacturer but the finished product shall meet all requirements of this Section. All coats of multi-coat systems shall be supplied by the same manufacturer. Multi-component coatings shall be prepackaged in the required ratios.

975-1.2 Environmental Requirements: Coating materials and their waste shall be characterized as non-hazardous as defined by Resource Conservation and Recovery Act (RCRA) Subarticle C rules, Table 1 of 40 CFR 261.24 Toxicity Characteristic.

Volatile Organic Compounds (VOC) shall be less than 3.5 pounds per gallon when tested in accordance with ASTM D3960.

975-1.3 Approved Product List (APL): All polymeric coating materials except the materials in 975-4 shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their products shall submit the product data sheets, performance test reports from AASHTO Product Evaluation & Audit Solutions, or an independent laboratory showing that the product meets the requirements of this Section, a Product SDS or performance test reports showing percent weight compositional analysis including Chemical Abstract Number, ACGIH time weighted average and ceiling exposure limits for all components, lower and upper explosive limits, flash point, boiling point, amount of volatile organic compounds by weight, and specific gravity for each component of the coating system, and a APL application in accordance with Section 6.

975-1.4 Packaging and Labeling: Materials shall be shipped in containers legibly marked with application instructions, lot number, batch number, date of manufacture, shelf life, and Department APL number. Each lot or batch manufactured must have a unique number.

975-1.5 Coating Identification: When applicable, the Department will conduct Fourier Transform Infrared Spectroscopy (FTIR) analysis on coating system components for material identification.

975-2 Structural Steel Coating Systems.

975-2.1 General: Structural steel coatings shall meet the application requirements of Section 560. Prepare and coat sixteen flat and four composite test panels in accordance with AASHTO R-31 (in color White, Grey, or Green) for each coating system proposed for approval and submit to the State Materials Office (SMO). Samples will be subject to verification testing by the Department, as identified in 975-2.2. In addition, submit a 1-quart wet sample of each component of each coating system, one container of compatible caulk to the SMO.

975-2.2 Performance Requirements: Each coating system will be subject to the testing identified in 975-2.2.1 and 975-2.2.2. All coatings, regardless of color, shall meet the requirements in Table 975-1.

975-2.2.1 Random Laboratory Verification Testing: Prepare and coat twelve flat test panels for random laboratory verification testing.

975-2.2.2 Outdoor Exposure Testing: Prepare and coat eight test panels (four flat and four composite) for exposure at the Department's outdoor test site. Panels will be tested in accordance with ASTM G7.

Table 975-1 Structural Steel Coating System Performance Requirements		
Laboratory Testing		
Property	Test Method	Acceptance Criteria
Slip Coefficient	AASHTO R 31 Test No. 1	Min. Class B (primer only)
Salt Fog Resistance	AASHTO R 31 Test No. 2 ASTM D610	Blister Value = 10 Average Rust Creep at the Scribe ≤ 3/32” Rust grade ≥ 9S, 9G, 9P after 8,760 hours
Salt Fog Resistance Unscribed		Blister Value = 10 Rust grade ≥ 9S, 9G, 9P after 8,760 hours
Cyclic Weathering Resistance	AASHTO R 31 Test No. 3	Blister Value = 10 Average Rust Creep at the Scribe ≤ 6/32”, Color Retention $\Delta E^*_{ab} \leq 8.0$, Gloss loss≤ 33% after 15 cycles – 336 hours each cycle
Abrasion Resistance	AASHTO R 31 Test No. 4	Wear Index ≤ 2.7 mg/cycle
Adhesion	ASTM D4060 1,000 Cycles, CS-17 Wheel, 1 kg. Weight	Avg. system tensile strength ≥ 800 psi
2-Year Outdoor Testing		
Property	Test Method	Acceptance Criteria
Rusting	ASTM D610 ASTM D1654 a (scribed) ASTM D1654 (un-scribed)	Rust Grade ≥ 9S, 9G, 9P Rating of Failure at Scribe ≥ 9 After 2-Years
Blistering	ASTM D714	Blister Value = 10 After 2-Years
Adhesion	ASTM D4541; annex A4	Avg. Tensile Strength ≥ 800 psi (un-scribed area) After 2-Years
Color Retention	ASTM D2244	Avg. $\Delta E^*_{ab} \leq 8.0$ After 2-Years
Gloss	ASTM D523	Avg. ≤ 33% loss of gloss After 2-Years

975-2.3 Structural Steel Coating Systems for New Structures: Systems must meet the general composition requirements of Table 975-2 and this section.

Table 975-2 Structural Steel Coating System General Composition Requirements			
Primer	Intermediate	Finish	Clear (Optional)
Inorganic Zinc-Rich Ethyl Silicate	None	Inorganic Ethyl Silicate	Manufacturers Recommendation
Inorganic Zinc-Rich Ethyl Silicate	Cycloaliphatic Amine Epoxy Or Polyamide Epoxy	Polyurethane	
		Polysiloxane	
		Acrylic	
		Fluoropolymer	
Inorganic Zinc-Rich Ethyl Silicate	Polyurethane (Epoxy Stripe)	Fluoropolymer	

975-2.3.1 High Performance Coating Systems (Color Pigmented):

975-2.3.1.1 Prime Coat: Provide inorganic zinc-rich primers consisting of zinc dust, functional additives, and an inorganic binder, with appropriate solvents. The composition of the primer shall consist of an inorganic self-curing vehicle, that contains solvent-reducible silicates, titanates, and polymeric versions of the silicates. Zinc dust pigment shall contain a minimum of 77% zinc dust by weight and a maximum lead level of 0.01% in accordance with ASTM D520. The manufacturer shall identify the amount of zinc dust on the product label. The performance requirements for gloss and color retention are not applicable.

975-2.3.1.2 Intermediate Coat: Intermediate coatings must meet Table 975-2. Epoxies must be a cycloaliphatic amine or polyamide.

975-2.3.1.3 Finish Coat: The finish coat shall provide the color and gloss required for the completed coating system. A finish coat may be comprised of a single pigmented coat or a pigmented coat with a clear coat that meets Table 975-2.

975-2.3.1.4 Clear Coat: The clear coat may contain a dissipating colorant. The dissipating colorant shall be visible for a minimum of 12 hours after application and shall completely dissipate within 96 hours after application.

975-2.3.2 Interior Box Girder Coating: The interior coat shall be one coat of white epoxy paint meeting 975-2.3.1.2 and listed on the Department's APL. Faying surfaces and areas to be stud welded are to be masked off and coated with a zinc-rich primer from the APL. The performance requirements for gloss and color retention are not applicable.

975-2.4 Structural Steel Coating Systems for Existing Structures: Systems must meet the general composition requirements of Table 975-3 and this section.

Table 975-3 Structural Steel Coating System General Composition Requirements			
Primer	Intermediate	Finish	Clear (Optional)
Organic Zinc-Rich Epoxy Or Inorganic Zinc-Rich Ethyl Silicate	None	Inorganic Ethyl Silicate	Manufacturers Recommendation
Organic Zinc-Rich Epoxy Or Inorganic Zinc-Rich Ethyl Silicate	Cycloaliphatic Amine Epoxy Or Polyamide Epoxy	Polyurethane	
		Polysiloxane	
		Acrylic	
		Fluoropolymer	

975-2.4.1 Prime Coat: Provide inorganic or organic zinc-rich primers consisting of zinc dust, functional additives, and an organic binder with appropriate solvents. The composition of the primer shall consist of an organic vehicle that may chemically cure or may dry by solvent evaporation. Zinc dust pigment shall contain a minimum of 77% zinc dust by weight and a maximum lead level of 0.01% accordance with ASTM D520.

Organic zinc-rich primers shall be used as galvanizing repair compounds for areas greater than 100 square inches.

975-2.4.2 Intermediate Coat: Intermediate coatings must meet Table 975-3 E. Epoxies must be a cycloaliphatic amine or polyamide.

975-2.4.3 Finish Coat: Finish coating shall provide the color and gloss required for the completed coating system. A finish coat may be comprised of a single pigmented coating or a pigmented coating with a clear coat.

975-2.4.4. Clear Coat: The clear coat may contain a dissipating colorant. The dissipating colorant shall be visible for a minimum of 12 hours after application and shall completely dissipate within 96 hours after application.

975-3 Galvanized Steel Coating System.

Coatings applied over galvanized steel shall meet the requirements of Table 975-2 with the exception that test panels shall be galvanized in accordance with ASTM A123 prior to application of subsequent coatings.

Coatings applied over galvanized steel strain poles, mast arms, and monotube assemblies shall meet the requirements of Section 649 and 975-4.

975-4 Paint for Galvanized Steel Strain Poles, Mast Arms, Monotube Assemblies, Conventional Light Pole Assemblies, and Aluminum Poles, Pedestals, and Posts.

Paint systems shall meet the color requirements as specified in the Contract Documents. All paint systems shall possess physical properties and handling characteristics that are compatible with the application requirements of Section 649 for galvanized steel and Section 646 and 715 for aluminum. Materials shall be specifically intended for use over galvanized steel or aluminum, as appropriate. Paint systems shall exhibit no loss of adhesion or total color difference (ΔE^*_{ab}) greater than 8.0 units for five years after final acceptance as specified in 5-11. Cumulative surface area of delamination in excess of 100 square inches will constitute an adhesion failure. Delamination shall be defined as any area of exposed metal surface subsequent

to hand tool cleaning in accordance with SSPC-SP2. A ΔE^*_{ab} value exceeding 8.0 units per the International Commission on Illumination L*a*b* 1976 (CIELAB) space and color difference formula, measured in accordance with ASTM D2244, will constitute a color retention failure.

The Department will measure and enter in the Department's database the CIELAB color chromaticity coordinates for the color of the top coat of sample coupons provided as required by 649-4.3 using a BYK-Gardner Handicolor colorimeter using D65 illuminant and 2-degree geometry settings. The Department-measured CIELAB chromaticity coordinates shall define the initial color and will be used for resolution of color retention failures and the resolution of color retention disputes.

975-5 Elastomeric Coatings.

975-5.1 General: Use an elastomeric coating system to provide a waterproof barrier over post-tensioning anchorages or other areas designated in the Plans. The components of the coating system shall be supplied by a single manufacturer and sold as a waterproof coating system. The surface preparation and application of the coating system shall be performed in strict accordance with the manufacturer's specifications. Upon request, submit a one quart wet sample of each component of each coating system to the SMO.

975-5.2 Physical Properties: The use of an epoxy prime coat is dependent upon the requirements of the manufacturer's waterproofing system. The polyurethane chemistry may be either waterborne aromatic (moisture-curing) or aromatic (moisture-sensitive). The elastomeric coating shall meet the requirements in Table 975-4.

Table 975-4
Elastomeric Coatings Performance Requirements

Property	Test Method	Acceptance Criteria
Hardness, Shore A	ASTM D2240	Between 60 and 90
Tensile Strength	ASTM D412	≥750 psi
Elongation	ASTM D412	≥400%
Tear Strength	ASTM C957	>70 psi
Abrasion Resistance H-18 wheels 1,000 gm/wheel	ASTM C957	≤350 mg loss / 1,000 revs.
Crack Bridging 1,000 Cycles	ASTM C957	System Passes
Elongation Recovery	ASTM C957	≥94%

975-5.3 System Modifications for Use on Exposed External Anchorages: Provide the elastomeric coating system with a 100% acrylic aliphatic polyurethane top coating where required as shown on Standard Plans Index 462-002, or when applied to other exposed external surfaces. Manufacturers of the elastomeric coating system shall include the acrylic top coating as part of the elastomeric coating system for approval.

975-6 Class 5 Applied Finish Coatings.

975-6.1 General: All coatings shall possess physical properties and handling characteristics compatible with the application requirements of Section 400. Unless otherwise specified, the color of the finish coat shall meet FED-STD-595, Table VIII, Shade No. 36622, or No. 36642 for uncoated weathering steel bridges.

975-6.2 Coating Requirements: Prepare four, 4 inch by 8 inch (except as required below) fiber cement test panels with a mass of 7 to 9 pounds per square foot of surface area to perform the laboratory tests. Apply the finish coating to each test panel at a rate of 50 square feet per gallon, plus or minus 10 square feet per gallon. Seal the corners of all test panels with a high build epoxy or equivalent to prevent moisture ingress at corners and cut edges. Submit the samples to an independent laboratory for testing. Coating performance shall meet the requirements in Table 975-5. Upon request, submit a one quart wet sample of each component of each coating system to the SMO.

Table 975-5 Class 5 Applied Finish Coatings Performance Requirements		
Laboratory Testing		
Property	Test Method	Acceptance Criteria
Resistance to Wind Driven Rain	ASTM D6904	No visible water leaks, and if the rear face of the block is damp, the average gain in weight of the three 8”x16”x2” blocks must be less than 0.2 lb.
Freeze thaw resistance	AASHTO R 31	No disbondment
Water Vapor Transmission	ASTM D1653; Method B, Condition C	WVT≥10 perms
Abrasion Resistance	ASTM D968, 3,000 liters of sand	No loss of coating thickness ASTM D6132
Salt Spray (fog) resistance	ASTM B117, 2,000 hours	No disbondment
Fluorescent UV-Condensation Exposure	ASTM D4587, 2000 hours, 4 hours UV, 4 hours condensation	No blistering (ASTM D714), cracking (visual), or delamination (visual). chalking (ASTM D4214Method D) rating no less than 8.
Fungal Resistance	ASTM D3273	Rating of 10, ASTM D3274

975-7 Anti-Graffiti Coating Materials.

975-7.1 General Requirements: Anti-graffiti coatings intended for use under this specification shall be of a composition capable of preventing the adhesion of and facilitating the removal of acrylic, polyurethane, and alkyd spray paint. All anti-graffiti coatings shall possess the physical and handling characteristics that are compatible with the requirements of Section 563. The manufacturer shall designate non-sacrificial products as water cleanable in accordance with this Section.

Anti-graffiti coatings shall contain less than 5.0 pounds per gallon volatile organic compounds (VOC) as defined by 40 CFR Part 59, Subpart D, evaluated as per ASTM D3960.

The manufacturer shall supply the following additional information:

1. Technical data sheet that includes installation instructions and graffiti removal instructions by pressure washing with water.
2. Sacrificial Coating Removal instructions, as applicable.

3. Certification that non-sacrificial anti-graffiti coating shall not blister, crack, check, chalk, delaminate, or exhibit a color change of more than 8 dE94 (or dE76) CIE LAB units for a period of one year after installation.

975-7.2 Performance Requirements: For laboratory testing, use flat test panels prepared in accordance with AASHTO R 31.

Outdoor exposure testing will be performed by the Department, if applicable. Submit four, 4 inch by 8 inch fiber cement test panels to the SMO. Panels will be exposed at the Department's outdoor test site in accordance with ASTM G7. Coating performance shall meet the requirements in Table 975-6.

Upon request, submit a one quart wet sample of each component of each coating system to the SMO.

Table 975-6 Anti-Graffiti Coatings Performance Requirements		
Outdoor Exposure Testing – Non-Sacrificial		
Property	Test Method	Acceptance Criteria
Graffiti Resistance (water cleanable)	FM 5-580: 6 months exposure at FDOT test site (2500 psi using pressure washer)	Complete removal of solvent based acrylic, and alkyd based spray paint. No delamination or visual defects.

Laboratory Testing - Sacrificial		
Property	Test Method	Acceptance Criteria
Cyclic Weather Testing	AASHTO R 31: no salt fog, 95°F, 0%- 90% Relative Humidity, 500 hours, alternating RH every 100 hours	No melting or disbondment
Outdoor Exposure Testing - Sacrificial		
Property	Test Method	Acceptance Criteria
Sacrificial Coating removability	FM 5-580: 6 months exposure at FDOT test site (2500 psi using pressure washer)	Complete removal of solvent based acrylic, and alkyd based spray paint from substrate

SECTION 981
TURF MATERIALS

981-1 General.

The types of seed and sod will be specified in the Contract Documents. All seed and sod shall meet the requirements of the Florida Department of Agriculture and Consumer Services and all applicable state laws, and shall be approved by the Engineer before installation.

All seed, sod and mulch shall be free of noxious weeds and exotic pest plants, plant parts or seed listed in the current Category I "List of Invasive Species" from the Florida Exotic Pest Plant Council (FLEPPC, https://www.fleppc.org). Any plant officially listed as being noxious or undesirable by any Federal Agency, any agency of the State of Florida or any local jurisdiction in which the project is being constructed shall not be used. Any such noxious or invasive plant or plant part found to be delivered in seed, sod or mulch will be removed by the Contractor at his expense and in accordance with the law.

All materials shall meet plant quarantine and certification entry requirements of Florida Department of Agriculture & Consumer Services, Division of Plant Industry Rules.

981-2 Seed.

The seed shall have been harvested from the previous year's crop. All seed bags shall have a label attached stating the date of harvest, LOT number, percent purity, percent germination, noxious weed certification and date of test.

Each of the species or varieties of seed shall be furnished and delivered in separate labeled bags. During handling and storing, the seed shall be cared for in such a manner that it will be protected from damage by heat, moisture, rodents and other causes.

All permanent and temporary turf seed shall have been tested within a period of six months of the date of planting.

All permanent and temporary turf seed shall have a minimum percent of purity and germination as follows:

1. All Bahia seed shall have a minimum pure live seed content of 95% with a minimum germination of 80%.
2. Bermuda seed shall be of common variety with a minimum pure live seed content of 95% with a minimum germination of 85%.
3. Annual Type Ryegrass seed shall have a minimum pure live seed content of 95% with a minimum germination of 90%.

981-3 Sod.

981-3.1 Types: Unless a particular type of sod is called for in the Contract Documents, sod may be either centipede, bahia, or bermuda at the Contractor's option. It shall be well matted with roots. Where sodding will adjoin, or be in sufficiently close proximity to, private lawns, other types of sod may be used if desired by the affected property owners and approved by the Engineer.

981-3.2 Dimensions: The sod shall be taken up in commercial-size rectangles, or rolls, preferably 12 inches by 24 inches or larger, except where 6 inch strip sodding is called for, or as rolled sod at least 12 inches in width and length consistent with the equipment and methods used

to handle the rolls and place the sod. Sod shall be a minimum of 1-1/4 inches thick including a 3/4 inch thick layer of roots and topsoil. Reducing the width of rolled sod is not permitted after the sod has been taken up from the initial growing location. Any netting contained within the sod must be certified by the manufacturer to biodegrade within one year.

981-3.3 Condition: The sod shall be sufficiently thick to secure a dense stand of live turf. The sod shall be live, fresh and uninjured, at the time of planting. It shall have a soil mat of sufficient thickness adhering firmly to the roots to withstand all necessary handling. It shall be planted within 48 hours after being cut and kept moist from the time it is cut until it is planted. No sod which has been cut for more than 48 hours may be used unless specifically authorized by the Engineer. A letter of certification from the turf Contractor as to when the sod was cut, and what type, shall be provided to the Engineer upon delivery of the sod to the job site.

The source of the sod may be inspected and approved by the Engineer prior to being cut for use in the work.

981-4 Mulch.

The mulch material shall be compost meeting the requirements of Section 987, hardwood barks, shavings or chips; or inorganic mulch materials as approved by the Engineer; or hydraulically applied wood fiber mulch or bonded fiber matrix (BFM) for the establishment of turf material.

SECTION 982
FERTILIZER

982-1 Fertilizers.

Fertilizers shall comply with the State fertilizer laws.

The numerical designations for fertilizer indicate the minimum percentages (respectively) of total nitrogen, available phosphoric acid, and water-soluble potash, contained in the fertilizer. At least 50% of the nitrogen shall be from a slow-release source.

982-2 Certification.

The Engineer shall collect a copy of the fertilizer label and retain according to the FDOT retention policy. The label shall include guaranteed values for total nitrogen, available phosphoric acid, water-soluble potash, and sulfur.

982-3 Fertilizer Rates.

Soil laboratory fertilization recommendations are based on the amount (lbs) of nutrients (N, P_2O_5, K_2O) to apply per given area (usually 1,000 square feet.). From this recommendation it is necessary to select an appropriate fertilizer grade and then determine how much of this fertilizer to apply to the area.

If a complete fertilizer (containing all three primary nutrients) is not available in the ratio of N-P-K necessary to match the ratio required in the fertilizer recommendation, mixed-grade or single-nutrient fertilizers should be used to satisfy each nutrient requirement.

To calculate fertilizer rates:

1. Measure the area to be fertilized in square feet.
2. Select fertilizers to be used based on the soil testing laboratory recommendations by matching the ratio of nutrients recommended to the fertilizer grades available.
3. Determine the amount of fertilizer to apply to a given area (1,000 square feet.) by dividing the recommended amount of nutrient by the percentage of the nutrient (on a decimal basis) in the fertilizer. Apply no more than 0.25 lbs P_2O_5/1000 square feet per application prior to planting.
4. Adjust the amount of fertilizer to the project area.

SECTION 983
WATER FOR GRASSING

The water used in the grassing operations may be obtained from any approved source. The water shall be free of any substance which might be harmful to plant growth. Effluent water shall meet all Federal, State and local requirements.

SECTION 985
GEOSYNTHETIC MATERIALS

985-1 Description.

Geosynthetic materials are used for nonstructural and structural applications and shall be either geotextiles (woven or non-woven) or geogrids (woven or extruded) that are used for drainage, erosion control, reinforcement, separation or stabilization.

985-2 General Requirements.

985-2.1 Product Acceptance: All geosynthetic materials shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation. A separate application must be submitted for each geotextile type to be evaluated, showing that the product meets the applicable requirements.

Documentation	Requirements
Installation Instructions	Include surface preparations, installation, overlap or sewing instructions, and repair procedures.
AASHTO Product Evaluation & Audit Solutions: Audit Report, for Structural Geosynthetic Materials Only	Manufacturer's facility included on list of compliant producers
AASHTO Product Evaluation & Audit Solutions: Test Results	Product meets requirements of this Section
Product Label Photo	Displays the Product Name
Product Photo	Displays the significant features of the product as required in this section. Displays location of Manufacturer name and model number.
Technical Data Sheet	Uniquely identifies the product and includes product specifications, reporting requirements, and storage instructions

Products will be listed on the APL according to the geosynthetic application type.

985-2.2 Material Application: In addition to the general requirements, meet the following physical requirements:

985-2.3 Materials: The geosynthetic material shall be a woven, non-woven or extruded material consisting of long-chain polymeric filaments or yarns such as polypropylene, polyethylene, polyester, polyamides or polyvinylidene chloride formed into a stable network such that the filaments or yarns retain their relative position to each other. The base plastic shall contain stabilizers and/or inhibitors to make the filaments resistant to deterioration due to ultra-violet light, heat exposure and potential chemically damaging environment. The edges of the material shall be selvaged or otherwise finished to prevent the outer yarn from pulling away from the material and shall be free of any treatment which may significantly alter its physical properties.

985-2.4 Physical Requirements: Each geosynthetic material shall be tested by an independent third party in accordance with the methods shown. All testing and reported values, except Apparent Opening Size (AOS), are to be minimum average roll values in the weakest principal direction, unless indicated otherwise in this Section. Values for AOS are maximum average roll values.

985-2.5 Packaging and Labeling: Geosynthetics shall be packaged in a protective covering sufficient to protect the material from temperatures greater than 140 F, sunlight, dirt, and other debris during shipment and storage. The manufacturer's name, product name, style number, roll dimensions and LOT numbers must be clearly labeled on all packaging.

985-2.6 Overlaps and Seams: Overlaps shall be in accordance with the manufacturer's recommendations, unless specified otherwise in the Contract Documents for a particular application. To reduce overlaps, the geosynthetic material may be sewn together in accordance with the manufacturer's recommendations. Sew the seams with thread meeting the chemical requirements and minimum seam strength requirements for the application.

985-3 Drainage.

985-3.1 Application: Select geotextile materials based on the following applications:

Table 985-1
Drainage Applications

Geotextile Type	Description	Standard Plans Index
D-1	Revetment (Special)	
	Rock, Rubble without bedding stone	
	Ditch Pavement (Rubble Riprap) without bedding stone	524-001
D-2	Revetment (Standard)	
	Articulating Block	
	Gabions	524-001
	Rock, Rubble, and Broken Concrete with bedding stone	
	Ditch Pavement (Rubble Riprap) with bedding stone	524-001
	Joint Cover for Mechanically Stabilized Retaining Wall with Coarse Aggregate Backfill	
	Joint Cover for Mechanically Stabilized Retaining Wall Supporting Spread Footing Foundations	
D-3	Underdrain: Types II, III, and V	440-001
	French Drain	443-001
	Sheet Piling Filter	
	Filter Fabric Jacket (Culvert)	430-001
	Box Culvert Joints	400-289 and 400-291
	Concrete Pavement Subdrainage	446-001
	Joint Cover for Mechanically Stabilized Retaining Wall with Sand or Limerock Backfill	
D-4	Slope Pavement	
	Ditch Pavement (Sand-Cement Riprap or Concrete)	524-001

Table 985-1 Drainage Applications		
Geotextile Type	Description	Standard Plans Index
	Coarse Aggregate Wrap	
D-5	Separation Geotextile	
	Cast-In-Place Retaining Wall	

985-3.2 Physical Requirements: Materials for drainage applications must be tested in accordance with and meet the following physical requirements:

Table 985-2 Geotextile Selection	
In-situ Soil Type or Drainage Application	Class for Type D1, D2, D3 Materials
< 15% passing a No. 200 Sieve*	a
15% to 50% passing a No. 200 Sieve*	b
> 50% passing a No. 200 Sieve*	c
> 50% passing a No. 200 Sieve* with Plastic Index >7	d
MSE Joint Cover for Sand or Limerock Backfill	e
MSE Joint Cover for Coarse Aggregate Backfill	f
*as per AASHTO T88.	

Table 985-3 Drainage Geotextiles Test Methods and Requirements for Types D-1, D-2 and D-3			
Property/Test Method	D-1	D-2	D-3
Limitation	Woven Monofilament Geotextiles only	Woven Geotextiles only. No Slit Film Geotextiles	No Slit Film Geotextiles
Minimum Permittivity (Sec - 1) per ASTM D4491	D-1a = 0.7 D-1b = 0.2 D-1c = 0.1 D-1d = 0.1 D-1e = 0.25 D-1f = 1.5	D-2a = 0.7 D-2b = 0.2 D-2c = 0.1 D-2d = 0.1 D-2e = 0.25 D-2f = 1.5	D-3a = 0.5 D-3b = 0.2 D-3c = 0.1 D-3d = 0.1 D-3e = 0.7
Maximum AOS (mm, US Sieve No.) per ASTM D4751	D-1a = 0.425 (40) D-1b = 0.250 (60) D-1c = 0.212 (70) D-1d = 0.300 (50) D-1e = 0.212 (70) D-1f = 0.600 (30)	D-2a = 0.425 (40) D-2b = 0.250 (60) D-2c = 0.212 (70) D-2d = 0.300 (50) D-2e = 0.212 (70) D-2f = 0.600 (30)	D-3a = 0.425 (40) D-3b = 0.250 (60) D-3c = 0.212 (70) D-3d = 0.300 (50) D-3e = 0.212 (70)
Minimum Grab Tensile Strength (lbs) per ASTM D4632	315	Woven Monofilament = 248 Other Woven Geotextiles = 315	Elongation <50% = 248 Elongation ≥50% = 158
Mass per Unit Area (oz/sy) per ASTM D5261	Provide Test Result	Provide Test Result	Provide Test Result
Minimum Puncture Strength (lbs) per ASTM D6241	618	Woven Monofilament = 495 Other Woven Geotextiles = 618	Elongation <50% = 495 Elongation ≥50% = 309
Minimum Trapezoidal Tear (lbs) per ASTM D4533	113	Woven Monofilament = 57 Other Woven Geotextiles: = 113	Woven Monofilament = 57 Other Geotextiles: Elongation <50% = 90 Elongation ≥50% = 57
Minimum UV Resistance per ASTM D4355 (% Retained Strength)	50% @500 hours	50% @500 hours	50% @500 hours

Table 985-4 Test Methods and Requirements for Drainage Geotextiles Types D-4 and D-5		
Property/Test Method	D-4	D-5
Minimum Permittivity (Sec^{-1}) per ASTM D4491	0.5	0.5
Maximum AOS (mm, US Sieve No.) per ASTM D4751	0.425 (40)	0.212 (70)
Minimum Grab Tensile Strength (lbs) per ASTM D4632	180	90
Mass per Unit Area (oz/sy) per ASTM D5261	Provide Test Result	Provide Test Result
Minimum Puncture Strength (lbs) per ASTM D6241	223	223
Minimum Trapezoidal Tear (lbs) per ASTM D4533	70	40
Minimum UV Resistance per ASTM D4355 (% Retained Strength)	50% @500 hours	50%@500 hours

985-4 Erosion Control.

985-4.1 Application: Materials may contain natural fibers added to acceptable plastic erosion mats for the sole purpose of facilitating turf growth. However, materials used for erosion control applications must be tested without any natural fiber components in accordance with and meet the physical requirements Table 985-6.

Table 985-5 Erosion Control Applications	
Type	Description
E-1	Staked Silt Fence
E-2	Wind Screen
E-3	Plastic Erosion Mat (Turf Reinforcement Mat) (Type 1)
E-4	Plastic Erosion Mat (Turf Reinforcement Mat) (Type 2)
E-5	Plastic Erosion Mat (Turf Reinforcement Mat) (Type 3)

985-4.2 Physical Requirements: Each geosynthetic material shall meet the following requirements:

Table 985-6 Test Methods and Requirements for Erosion Control Materials					
Property/Test Method	E-1	E-2	E-3	E-4	E-5
Permittivity (Sec^{-1}) per ASTM D4491	0.05	0.05	NA	NA	NA
Grab Tensile Strength (lbs) per ASTM D4632	90	90	NA	NA	NA
Minimum UV Resistance per ASTM D4355 (% Retained Strength)	80% @500 hours	80% @150 hours	80% @500 hours		
Tensile Strength **(lbs/ft) per ASTM D6818 or D5035	NA	NA	135x70	275x135	550x275

Table 985-6 Test Methods and Requirements for Erosion Control Materials					
Property/Test Method	E-1	E-2	E-3	E-4	E-5
Filtration Efficiency (%) per ASTM D5141	75% and min. flow rate of 0.3 gal/sf/min	NA	NA	NA	NA
Design Shear***	NA	NA	≧2.1 psf	≧3.6 psf	≧5.0 psf
**Tensile Strength is expressed in units of measure of lbs/ft, in machine direction and cross direction as MD x CD. ***Design Shear limits for Erosion mats must be determined by 30 minutes sustained flow in an unvegetated state as determined by tests performed by Utah State University, Texas Transportation Institute or an independent testing laboratory approved by the State Drainage Engineer.					

985-5 Structural.

985-5.1 Applications: Materials for reinforcement, separation and stabilization applications must be tested in accordance with and meet the physical requirements below. The ultimate tensile strength of all R-1 materials must be at least 4800 pounds per foot in both the machine and cross machine directions.

Table 985-7 Reinforcement, Separation and Stabilization Applications	
Type	Description
R-1	Geosynthetic Reinforced Soil (GRS-IBS)
R-2	Reinforcement of Foundations over Soft Soils
R-3	Reinforced Soil Slopes
R-4	Reinforced Embankment
R-5	Construction Expedient

985-5.2 Physical Requirements: Each geosynthetic material shall be tested in accordance with the following requirements:

Table 985-8 Test Methods and Reporting Requirements for Structural Geosynthetics			
Property/Test Method	Structural Application Type	Test Methods for Woven Geotextiles	Test Methods for Woven or Extruded Geogrids
Permittivity (sec^{-1})	R - 1, 2, 3, 4, 5	ASTM D4491	NA
UV Stability (Min Retained Strength @500 hr)	R - 3	ASTM D4355	ASTM D4355
Puncture Strength (lbs)	R - 5	ASTM D6241	NA
Grab Strength (lbs)	R - 5	ASTM D4632	NA
Opening Size	R - 1, 2, 3, 4, 5	AOS (US Sieve No.) ASTM D4751	Aperture Size (in x in)
Tensile Strength (lbs/ft)		ASTM D4595	ASTM D6637
Machine Direction Ultimate, (T_{ult})			
2% Strain	R - 1, 3		
5% Strain	R - 2, 3, 4, 5		

Table 985-8 Test Methods and Reporting Requirements for Structural Geosynthetics			
Property/Test Method	Structural Application Type	Test Methods for Woven Geotextiles	Test Methods for Woven or Extruded Geogrids
10% Strain	R - 1, 2, 3, 4, 5		
Cross Direction Ultimate			
2% Strain	R - 1, 3,		
5% Strain	R - 2, 3, 4, 5		
10% Strain	R - 1, 2, 3, 4, 5		
Strain @ Ultimate Tensile Strength	R - 1, 2, 3, 4, 5		
Tear Strength (lbs)		ASTM D4533	NA
Machine Direction	R - 5		
Cross Direction	R - 5		
Soil-Geosynthetic Friction	R - 1, 2, 3	ASTM D5321	ASTM D5321/6706
Pullout Resistance	R - 3	ASTM D6706	ASTM D6706
Creep Resistance-T_{creep} (lbs/ft)	R - 2, 3	ASTM D5262	ASTM D5262
Creep Reduction Factor (T_{ult}/T_{creep})	R - 2, 3	NA	NA
Installation Damage (RF_{ID})		AASHTO R69	AASHTO R69
Sand	R - 2, 3, 4		
Limestone	R - 2, 3, 4		
Durability (RF_D)		AASHTO R69	AASHTO R69
Chemical	R - 2, 3, 4		
Biological	R - 2, 3, 4		
Joint Strength (RF_j)			
Mechanical	R - 2, 3	GRI: GT7	GRI: GG4(a) & GG4(b)
Sewn	R - 2, 3	ASTM D4884	NA

SECTION 987
SOIL LAYER MATERIALS

987-1 Description.

All material shall be suitable for plant growth. The organic matter content of the soil layer after mixing shall be a minimum of 2.5%, a maximum of 10%, in accordance with FM 1-T267 and have a pH value of 5.5 or greater and less than or equal to7.0 as determined in accordance with FM 5-550. The organic matter content shall be created using any of the following materials.

987-2 Materials.

Soil layer materials may be obtained from either, or a combination of, the following sources:

1. Excavation within the limits of construction on the project. Such material may be stockpiled or windrowed on the project in areas approved by the Engineer.
2. Designated borrow pits for the project.
3. From other sources of organic soil materials provided by the Contractor.

987-2.1 Organic Soil: This may consist of muck, mucky peat and peat and shall have an organic matter content of 30% or more if the mineral fraction is more than 50% clay, or more than 20% organic matter if the mineral fraction has no clay.

987-2.2 Blanket Material: Meet the material classification shown in the Plans and Standard Plans, Index 120-001.

987-2.3 Compost: Meet the requirements of Florida Department of Environmental Protection Rule 62.709.550 Type Y (yard waste), Type YM (yard waste and manure), Type A (municipal solid waste compost) or Rule 62.640.850 Type AA (composted biosolids) and have unrestricted distribution.

987-2.3.1 Compost for use as a Soil Amendment: If the electrical conductivity (EC) value of the compost exceeds 4.0dS (mmhos/cm) based on the saturated paste extract method, the compost shall be leached with water prior to application.

987-2.3.2 Compost for use as a Mulch: The compost shall contain no foreign matter, such as glass, plastic or metal shards. The compost shall be slightly coarse to coarse in nature (over half of the solids shall be from particles 1/2 inches in size and no greater than 6 inches). Preference shall be given to compost or mulch made from uncontaminated woody waste materials.

987-2.4 Landscape Soil: Landscape soil must be sandy loam or loamy sand with properties of AASHTO classification A-2-4 or A-4. The soil must have an organic matter content of 5 to 10% using the loss on ignition (LOI) test in accordance with FM 1-T267 from a soil testing laboratory approved in accordance with 105-7. Soil must be free of litter and deleterious substance such as cans, debris, particles greater than 0.50 inches, and rinsate containing lime or toxic materials.

Soil must be free of noxious plants or propagules of plants listed in Florida Rule 5B-57.007, and invasive exotic plants listed under Category I Florida Exotic Plant Pest Council.

Where shown in the Plans or when approved by the Engineer, existing soil may be amended with compost or biosolids to meet the requirements of this Section. Use compost in accordance with FDEP Rule 62.709.550 and 62.709.600. Use biosolids in accordance with Florida Rule 62.640.850.

SECTION 990
TEMPORARY TRAFFIC CONTROL DEVICE MATERIALS

990-1 General.

This Section specifies the material requirements for temporary traffic control devices.

990-2 Retroreflective Sheeting for Temporary Traffic Control Devices.

990-2.1 Bands for Temporary Tubular Markers, Vertical Panels, Barricades, and other Devices: Bands for temporary tubular markers, vertical panels, barricades, and other devices shall meet the requirements of ASTM D4956 for Type III or higher retroreflective sheeting materials identified in Section 994.

990-2.2 Collars for Traffic Cones: Collars for traffic cones shall meet the requirements of ASTM D4956 Type III or higher retroreflective prismatic sheeting materials identified in Section 994 including supplementary requirements for reboundable sheeting. The outdoor weathering shall be for 6 months for all sheeting types.

990-2.3 Drums: Drums shall meet the requirements of ASTM D4956 for Type III or higher retroreflective sheeting materials identified in Section 994 including supplementary requirements for reboundable sheeting.

990-2.4 Sign Panels: Meet the requirements of 990-8.

990-3 Portable Devices (Arrow Boards, Changeable Message Signs, Regulatory Signs, Radar Speed Display Units and Truck Mounted Changeable Message Signs), Automated Flagger Assistance Devices).

990-3.1 General: All portable devices shall meet the physical display and operational requirements of the Manual on Uniform Traffic Control Devices (MUTCD) and be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product must submit the following:

1. Certification showing that the product meets the requirements of this Section.

2. Drawings of the device along with technical information necessary for proper application, field assembly, and installation.

Portable devices shall meet the following requirements:

3. Ensure that all assembly hardware less than 5/8 inch in diameter, including nuts, bolts, external screws and locking washers are Type 304 or 316 passivated stainless steel. Stainless steel bolts, screws and studs shall meet ASTM F593. Nuts shall meet ASTM F594. All assembly hardware greater than or equal to 5/8 inch in diameter shall be galvanized. Bolts, studs, and threaded rod shall meet ASTM A307. Structural bolts shall meet ASTM F3125, Grade A325.

4. The controllers and associated on-board circuitry shall meet the requirements of the Federal Communications Commission (FCC) Title 47, Subpart B, Section 15 regulations concerning the emission of electronic noise by Class A digital devices. All electronic assemblies shall meet the requirements of NEMA TS-4-2016 Section 2.

5. The controller and associated on-board circuitry shall not be affected by mobile radio, or any other radio transmissions.

6. An operator's manual shall be furnished with each unit.

7. All portable devices shall be permanently marked with, manufacturer's name or trademark, model/part number, and date of manufacture or serial number.

8. Portable devices and trailers shall be delineated on a permanent basis by affixing retroreflective sheeting in a continuous line on the face of the trailer as seen by oncoming road users.

990-3.1.1 Electrical Systems:

990-3.1.1.1 Solar Powered Unit: The solar powered unit shall meet the following:

1. The unit shall provide automatic recharging of power supply batteries to normal operating levels with meters showing charge.

2. Solar array recovery time for arrow boards and regulatory signs shall be accomplished in a maximum of three hours.

3. Arrow boards and changeable message signs shall be designed to provide 180 days of continuous operation with minimum onsite maintenance.

990-3.1.1.2 Battery Life Test: Meet the following:

1. The photovoltaic unit shall be designed to provide 21 days of continuous operation without sunlight with a minimum of onsite maintenance for arrow boards and changeable message signs, or 10 days of continuous operation without sunlight with a minimum of onsite maintenance for regulatory signs and radar speed display units, or 2 days of continuous operation without sunlight with a minimum of onsite maintenance for Automated Flagger Assistance Devices signs.

2. The battery shall be equipped with a battery controller to prevent overcharging and over-discharging. An external battery level indicator shall be provided.

3. The battery, controller, and power panel shall be designed to be protected from the elements and vandalism.

4. Automatic recharging of power supply batteries shall be provided with charge indicator meter.

5. An AC/DC battery charger unit shall be provided.

990-3.1.2 Display Panel and Housing:

1. The display housing assembly shall be weather-tight.

2. Except for Automated Flagger Assistance Devices, the display assembly shall be equipped with an automatic dimming operational mode capable of a minimum of 50% dimming and a separate manual dimmer switch

3. The display panel background and frame for the display assembly shall be painted flat black and shall meet Federal Specification TT-E-489.

4. The display panel for arrow boards and changeable message signs, when raised in the upright position, shall have a minimum height of 7 feet from the bottom of the panel to the ground, in accordance with the MUTCD. The display panel for radar speed display units, when raised in the upright position, will have a minimum height of 5 feet from the bottom of the panel to the ground.

5. The regulatory speed sign panel for regulatory signs and radar speed display units, when raised in the upright position, shall have a minimum height of 7 feet from the bottom of the regulatory sign panel to the ground.

6. The unit shall have an accessible mechanism to easily raise and lower the display assembly. A locking device shall also be provided to ensure the display panel will remain in the raised or lowered position.

7. The display panel for changeable message signs shall have a safety system to protect against the panel falling from the trailer to the roadway should the panel separate from the lift system.

990-3.1.3 Controller: The Controller shall meet the following:

1. Controller and control panel shall be housed in a weather, dust, and vandal resistant lockable cabinet.

2. Controller and associated on-board circuitry shall meet the requirements of the FCC Title 47, Subpart B, Section 15 regulations concerning the emission of electronic noise by Class A digital devices.

3. For changeable message signs and arrow boards ensure that the sign control software provides an on-site graphical representation that visibly depicts the message displayed on the sign face.

4. For changeable message signs, if remote communication is included, ensure that the sign controller is addressable through the Ethernet communications network using software that complies with the National Transportation Communications for ITS Protocol (NTCIP) 1101 base standard, including all amendments as published at the time of contract letting, the NTCIP Simple Transportation Management Framework, and conforms to Compliance Level 1. Ensure that the software implements all mandatory objects in the supplemental requirement SR-700-4.1.1-01, FDOT Dynamic Message Sign NTCIP Requirements, as published on the FDOT State Traffic Engineering and Operations Office web site at the time of contract letting. Ensure that the sign complies with the NTCIP 1102v01.15, 2101 v01.19, 2103v02.07, 2201v01.15, 2202 v01.05, and 2301v02.19 standards. Ensure that the sign complies with NTCIP 1103v02.17, section 3. Ensure that additional objects implemented by the software do not interfere with the standard operation of mandatory objects.

990-3.1.4 Support Chassis: The support chassis shall meet the following:

1. The support chassis shall be self-contained and self-supporting without the use of additional equipment or tools.

2. Both trailer and truck-mounted units are allowed for arrow boards and changeable message signs. Trailer mounted units are required for regulatory signs and radar speed display units. Automated Flagger Assistance Devices may be trailer or non-trailer units.

a. Trailer mounted unit:

1. The sign, power supply unit and all support systems shall be mounted on a wheeled trailer.

2. The trailer shall be equipped with Class A lights, using a plug adaptor.

3. The trailer shall be equipped with adjustable outrigger leveling pads, one on each of the four frame corners.

4. The trailer shall be designed to be set up at the site with its own chassis and outriggers, without being hitched to a vehicle.

5. The trailer shall be equipped with fenders over the tires and shall be made from heavy-duty material sufficient to allow a person to stand and operate or perform maintenance on the unit.

6. The trailer shall meet all equipment specifications set forth in Chapter 316 of the Florida Statutes, and by such rule, regulation or code that may be adopted by the Department of Highway Safety and Motor Vehicles.

990-3.2 Portable Arrow Board:

990-3.2.1 Arrow Board Matrix:

1. The minimum legibility distance for various traffic conditions are based on the decision-sight distance concept. The minimum legibility distance is the distance at which a driver can comprehend the arrow board message on a sunny day or a clear night. The arrow board size that is needed to meet the legibility distance is listed as follows:

Table 990-1

Type	Minimum Size	Minimum Number of Elements	Minimum Legibility Distance
B	30 by 60 inches	13	3/4 mile
C	48 by 96 inches	15	1 mile

Type B arrow boards may be used on low to intermediate speed (0 mph to 50 mph) facilities or for maintenance or moving operations on any speed facility. Type C arrow boards shall be used for all other operations on high-speed (50 mph and greater) facilities and may be substituted for Type B arrow boards on any speed facility.

2. Devices shall meet all arrow board displays identified in the MUTCD.

3. The element lens should be 5-3/4 inches in diameter. Smaller element lens diameters are permissible only if they provide an equivalent or greater brightness indication and meet the legibility criteria in 990-3.2.1(a).

4. The color of the light emitted shall be in accordance with the MUTCD.

5. There shall be a 360 degree hood for close-up glare reduction.

6. For solar powered arrow boards the bulbs shall provide a 350 candle power intensity for day use and an automatic reduction or dimming capacity for night use. The dimmed night operation shall provide adequate indication without excessive glare.

7. The flashing rate of the element shall not be less than 25 flashes or more than 40 flashes per minute as required in the MUTCD.

8. The minimum element “on time” shall be 50% for the flashing arrow and 25% for the sequential chevron.

990-3.3 Portable Changeable Message Sign:

990-3.3.1 Message Matrix:

1. Message matrix panel shall be a maximum height of 7 feet by a maximum width of 146 inches.

2. The matrix must be capable of displaying three lines of 8 characters using an 18 inch or 12 inch font. PCMS with a minimum font size of 18 inches shall be used on any speed facility. PCMS with a minimum font size of 12 inches may be used on facilities with speed limits of 45 mph or less.

3. The matrix must display characters that meet or exceed the numeral and letter sizes prescribed in the MUTCD and SHS (Standard Highway Signs) companion document. Fonts and graphics must mimic the characteristics of fonts and graphics defined in NEMA TS4, the MUTCD, and SHS.

4. Similar components shall be interchangeable.

990-3.3.2 Operation and Performance:

1. The message shall be displayed in upper case except when lower case is project specific and is allowed by the MUTCD.

2. The message matrix panel shall be visible from one-half mile.

3. The 18 inch letter height message shall be legible from 650 feet for nighttime conditions and 800 feet for normal daylight conditions.

4. The 12 inch letter height message shall be legible from 650 feet for nighttime conditions and 650 feet for normal daylight conditions.

5. Under variable light level conditions the sign shall automatically adjust its light source to maintain legibility.

6. The message panel shall have adjustable display rates, so that the entire message can be read at least twice at the posted speed.

7. The control panel shall have the capability to store a minimum 50 pre-programmed messages.

8. The controller in the control panel shall be able to remember messages during non-powered conditions.

9. The controller shall allow the operator to generate additional messages on site via the keyboard.

10. All messages shall be flashed or sequenced. In the sequence mode, the controller shall have the capability to sequence three line messages during one cycle.

990-3.4 Portable Regulatory Signs:

990-3.4.1 Sign Panel Assembly: The sign panel assembly shall consist of a 24 inches by 30 inches “SPEED LIMIT XX” sign panel and a “WHEN FLASHING” sign panel, intended to notify oncoming traffic the speed limit where workers are present. The sign panel assembly shall meet the following minimum physical requirements:

1. The sign panel shall fold down and be pinned in place for towing. Maximum travel height shall be 80 inches.

2. Construct the sign panel and light housing to allow the unit to be operated in the displayed position at speeds of 30 mph. Design the sign panel assembly to withstand transport speeds of 65 mph.

3. Construct the sign panel such that, when in the raised position, the sign panel will have a height of 7 feet from the bottom of the lowest panel to the ground, in accordance with the MUTCD.

4. Provide the unit with a mechanism to raise and lower the sign panel. Provide the unit with a device to lock the sign panel in the raised and lowered position.

990-3.4.2 Flashing Lights: Provide a pair of hooded PAR 46 LED advance warning flashing lamps on each side of the top of the sign panel. These lamps shall be visible day or night at a distance of one mile with a flash rate of approximately 55 flashes per minute.

The lamp lens should be at least 5-3/4 inches in diameter. Smaller diameter lens are permissible if they provide an equivalent or greater brightness indication and meet the legibility criteria above.

The color of the light emitted shall be in accordance with the MUTCD. For solar powered units, the bulbs shall provide a 350 candlepower intensity for day use and an automatic reduction or dimming capacity for night use. The dimmed night operation shall provide adequate indication without excessive glare.

990-3.5 Portable Radar Speed Display Unit:

990-3.5.1 Display Unit Panel and Housing: Meet the requirements of 990-3.1.2 and the following physical requirements as a minimum:

1. Provide capability to mount a 24 inches by 30 inches regulatory sign with interchangeable numbers showing the posted speed limit above the message display.
2. Provide legend "YOUR SPEED" either above or below the message display.

990-3.5.2 Message Display: The message display shall meet the following physical requirements as a minimum:

1. Provide a bright LED, two-digit speed display on a flat black background with bright yellow LEDs.
2. Each digit shall contain either a seven-segment layout or matrix-style design. Each digit shall measure a minimum 18 inches in height.
3. Speed display shall be visible from a distance of at least one-half mile and legible from a distance of at least 650 feet under both day and night conditions.
4. Display shall adjust for day and night operation automatically with a photocell.

990-3.5.3 Radar: The radar unit shall not be affected by normal radio transmissions and meet the following physical requirements as a minimum:

1. Approach-Only sensor.
2. Equipped with a low power K-Band transmitter.
3. Part 90 FCC acceptance, 3 amps, 10.8 V_{DC} to 16.6 V_{DC}. Fuse and reverse polarity protected.
4. Range of 1,000 feet for mid-size vehicle, capable of accurately sensing speeds of 10 mph to 99 mph with over speed function that operates when a vehicle approaches over the posted speed limit.

990-3.6 Truck Mounted Changeable Message Sign:

990-3.6.1 General: Truck mounted changeable message signs shall meet the physical display and operational requirements of the MUTCD and be listed on the APL.

1. Sign shall be secured on the vehicle for normal operation.
2. A fault light shall be located on rear of the sign and operate whenever the sign is displaying a message. The light shall flash at the same rate as the message being displayed.
3. An operator's manual shall be furnished with each sign.
4. The manufacturer name, model or part number, and date of manufacture or serial number shall be permanently affixed to the sign housing.

990-3.6.2 Display Panel and Housing:

1. The housing maximum size shall not exceed a width of 96 inches.
2. The housing shall be designed to withstand exposure to the elements and include a locking device to secure the housing from unauthorized entry.
3. Provisions (by convection or fan) shall be made for heat dissipation within the unit.
4. The message matrix panel background and frame for the dynamic message assembly shall be painted flat black, Federal Specification TT-E-489.
5. The face of the display shall be easily opened from the front. Faces that open up shall be locked to stay open far enough to allow for servicing of all message panel components.

6. The face of the sign shall be covered by an impact resistant polycarbonate face that aids against glare and includes an ultraviolet inhibitor to protect from fading and yellowing.

7. The display panel support structure, when raised in the upright position, shall be designed to allow for a minimum height of 7 feet from the bottom of the panel to the ground.

8. The unit shall have a manual and automatic control mechanism to raise and lower the display assembly. A locking device shall also be provided to ensure the display panel will remain in the raised or lowered position.

990-3.6.3 Message Matrix:

1. The matrix shall utilize light emitting diodes (LED).

2. LEDs used shall be amber (590 nm dominate wavelength) and shall meet the visibility requirements of this specification. LEDs shall have a viewing angle no less than 30 degrees. LED intensity shall not fall below 80 percent within three years.

3. All display modules shall be identical and interchangeable.

4. The matrix shall be capable of displaying a minimum of two lines of eight characters each, using a 10 inch font that meets the height to width ratio and character spacing requirements in the MUTCD, Section 2L.04 (paragraphs 05, 06, and 08) and Section 6F.60, paragraph 15.

5. The matrix shall provide variable letter, graphic and symbol sizes from 10 to 36 inches. The matrix must display characters that meet or exceed the numeral and letter sizes prescribed in the MUTCD and SHS companion document. Fonts and graphics must mimic the characteristics of fonts and graphics defined in NEMA TS4, the MUTCD, and SHS.

990-3.6.4 Electrical System:

1. The power supply shall be a 12 V_{DC} system designed to operate the sign with a dedicated battery that is charged by the vehicle electrical system, but isolated so it does not drain the vehicle battery.

2. All internal sign components shall be treated with a protective, weather-resistant polyurethane or silicone conformal coating to protect against the adverse effects of humidity and moisture.

990-3.6.5 Sign Controller:

1. The sign controller shall be housed inside the sign and shall be equipped with a security lockout feature to prevent unauthorized use.

2. An external weather-resistant, hand-held control keypad shall be used to display the message on the sign.

3. The sign controller shall have the capability to provide a predetermined or blank default message upon loss of controller function.

990-3.6.6 Operation and Performance:

1. The message shall be displayed in upper case.

2. The message matrix panel shall be visible from one-half mile. With a 10 inch character displayed, the sign shall be legible from a distance of 400 feet in both day and night conditions. Under variable light level conditions, the sign shall automatically adjust its light source to meet the 400 foot visibility requirement.

3. The sign shall have the capability to store a minimum of 40 common messages and graphics of which a minimum of 30 shall be user-programmable messages.

4. All messages shall be capable of being flashed or sequenced. In the sequence mode, the message shall consist of no more than two phases, with each phase consisting of no more than three lines of text. Both message dwell time and message flash rate shall be individually programmable.

990-3.7 Automated Flagger Assistance Devices (AFAD):

990-3.7.1 General: AFAD's shall meet the physical display and operational requirements in the MUTCD and be listed on the APL. Manufacturers seeking evaluation of their product for the APL must include detailed vendor drawings showing typical application of the device in accordance with Standard Plans, Index 102-603. All electronic assemblies shall meet the requirements of NEMA TS-5-2017 Section 4.

990-3.7.2 Stop/Slow Automated Flagger Assistance Devices: Provide a remotely operated Stop/Slow AFAD including a Stop/Slow sign that alternately displays the stop face and the slow face of a Stop/Slow paddle.

When a gate arm is used, ensure that the gate arm descends to a down position across the approach lane of traffic when the stop face is displayed and then ascends to an upright position when the slow face is displayed.

Ensure the gate arm is fully retroreflectorized on both sides, with vertical alternating red and white stripes at 16 inch intervals measured horizontally in accordance with the MUTCD. When the arm is in the down position blocking the approach lane:

1. The minimum vertical aspect of the arm and sheeting shall be 2 inches; and,

2. The end of the arm shall reach at least to the center of the lane being controlled.

990-3.7.3 Red/Yellow Lens Automated Flagger Assistance Devices: Provide a remotely operated Red/Yellow Lens AFAD that alternately displays a steadily illuminated circular red lens and a flashing circular yellow lens to control traffic.

Ensure that the Red/Yellow Lens AFAD includes a gate arm that descends to a down position across the approach lane of traffic when the steady circular red lens is illuminated and then ascends to an upright position when the flashing circular yellow lens is illuminated.

Ensure that the gate arm is fully retroreflectorized on both sides, with vertical alternating red and white stripes at 16 inch intervals measured horizontally in accordance with the MUTCD. When the arm is in the down position blocking the approach lane:

1. The minimum vertical aspect of the arm and sheeting shall be 2 inches; and,

2. The end of the arm shall reach at least to the center of the lane being controlled.

Do not provide a change interval between the display of the steady circular red indication and the display of the flashing circular yellow indication. Provide a steady illuminated circular yellow indication, with at least a 5 second duration, between the transition from flashing circular yellow indication and the display of the steady circular red indication. The Engineer may approve a different duration, provided it falls within the range recommended by the MUTCD.

990-4 Removable Tape.

990-4.1 General: Removable tape shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an

application in accordance with Section 6. Evaluation of Removable Tape will utilize data from an independent laboratory or data from AASHTO Product Evaluation & Audit Solutions.

990-4.2 Composition: Removable tape shall be one of the products listed on the APL. The pavement stripes and markings shall consist of high quality plastic materials, pigments, and glass spheres or other retroreflective materials uniformly distributed throughout their cross-sectional area, with a reflective layer of spheres or other retroreflective material embedded in the top surface. No foil type materials shall be allowed.

990-4.3 Retroreflectivity: The white and yellow pavement markings shall attain an initial retroreflectance of not less than 300 mcd/m^2/lx and 250 mcd/m^2/lx, respectively. Black pavement markings shall have a retroreflectance of less than 20 mcd/m^2/lx. The retroreflectance of the white and yellow pavement markings at the end of the six-month period shall not be less than 150 mcd/m^2/lx.

990-4.4 Thickness: The APL will list the specified thickness of each approved product.

990-4.5 Durability and Wear Resistance: When properly applied, the material shall provide neat, durable stripes and markings. The materials shall provide a cushioned resilient substrate that reduces sphere crushing and loss. The film shall be weather resistant and, through normal wear, shall show no significant tearing, rollback or other signs of poor adhesion. Durability is the measured percent of pavement marking material completely removed from the pavement. The pavement marking material line loss must not exceed 5.0% of surface area.

990-4.6 Conformability and Resealing: The stripes and markings shall be capable of conforming to pavement contours, breaks and faults under traffic at pavement temperatures recommended by the manufacturer. The film shall be capable of use for patching worn areas of the same types of film in accordance with the manufacturer's recommendations.

990-4.7 Tensile Strength: The stripes and markings shall have a minimum tensile strength of 40 psi when tested according to ASTM D638. A rectangular test specimen 6 inches by 1 inch by 0.05 inches minimum thickness shall be tested at a temperature range of 40°F to 80ºF using a jaw speed of 0.25 inches per minute.

990-4.8 Elongation: The stripes and markings shall have a minimum elongation of 25% when tested in accordance with ASTM D638.

990-4.9 Plastic Pull test: The stripes and markings shall support a dead weight of 4 pounds for not less than five minutes at a temperature range of 70°F to 80ºF. Rectangular test specimen size shall be 6 inches by 1 inch by 0.05 inches minimum thickness.

990-4.10 Adhesive: Precoat removable tape with a pressure sensitive adhesive capable of being affixed to asphalt concrete and portland cement concrete pavement surfaces without the use of heat, solvents, and other additional adhesives or activators. Ensure that the adhesive does not require a protective liner when the removable tape is in rolled form for shipment. Ensure that the adhesive is capable of temporarily bonding to the roadway pavement at temperatures of 50ºF and the above without pick-up distortion by vehicular traffic.

990-4.11 Color: Meet the requirements of 971-1.6.

990-4.12 Removability: Ensure that the manufacturer shows documented reports that the removable tape is capable of being removed intact or in substantially large strips after being in place for a minimum of 90 days and under an average daily traffic count per lane of at least 5,000 vehicles per day at temperatures above 40ºF, without the use of heat, solvents, grinding or blasting.

990-5 Temporary Raised Pavement Markers (RPMs).

Temporary RPMs shall meet the requirements of Section 970.

990-6 Temporary Glare Screen.

990-6.1 Design and Installation: Manufactured glare screen systems may be modular or individual units listed on the APL and shall meet the following requirements:

1. Glare screen units shall be manufactured in lengths such that when installed the joint between any one modular unit will not span barrier sections. Color shall be medium gray green, similar to AMS-STD-595A-34227.

2. Blades, rails and/or posts shall be manufactured from polyethylene, fiberglass, plastic, polyester or polystyrene, and be ultraviolet stabilized and inert to all normal atmospheric conditions and temperature ranges found in Florida.

3. For paddle type designs, the blade width shall not be more than 9 inches. Blades or screen for individual or modular systems shall be 24 inches to 30 inches high and capable of being locked down at an angle and spacing to provide a cut-off angle not less than 20 degrees.

4. For glare screen mounted on temporary concrete barrier, a strip (minimum 3-inch width and minimum 72 square inches) of reflective sheeting as specified in 994-2 must be placed on each side of a panel, centered in each barrier section (at a spacing not to exceed 15 feet) and positioned in such a manner as to permit total right angle observation by parallel traffic.

5. Prior to approval an impact test shall be performed by the manufacturer to verify the safety performance of the proposed system. The minimum impact strength of the posts, blades, rail and the barrier attachment design shall be sufficient to prevent the unit from separating from the barrier when impacted by a 3-inch outside diameter steel pipe traveling at 30 mph and impacting mid-height on the glare screen assembly.

6. All hardware shall be galvanized in accordance with ASTM A123 or stainless steel in accordance with AISI 302/305.

7. The anchorage of the glare screen to the barrier must be capable of safely resisting an equivalent tensile load of 600 pounds per foot of glare screen with a requirement to use a minimum of three fasteners per barrier section.

Alternative designs for temporary glare screen may be submitted as a Cost Savings Initiative Proposal in accordance with 4-3.9.

990-7 Temporary Traffic Control Signals.

990-7.1 General: Temporary traffic control signals shall meet the physical display and operational requirements of conventional traffic signal described in the MUTCD for portable traffic signals and be listed on the APL. The standard includes but is not limited to the following:

1. Use signal heads having three 12 inch vehicular signal indications (Red, Yellow and Green). Ensure there are two signal heads for each direction of traffic.

2. The traffic signal heads on this device will be approved by the Department.

3. Department approved lighting sources will be installed in each section in accordance with the manufacturer's permanent directional markings, that is, an "Up Arrow", the word "UP" or "TOP," for correct indexing and orientation within a signal housing.

4. The masts supporting the traffic signal heads will be manufactured with the lowest point of the vehicular signal head as follows:

a. Eight feet above finished grade at the point of their installation for "pedestal" type application or

b. Seventeen to 19 feet above pavement grade at the center of roadway for "overhead" type application.

5. The yellow clearance interval will be programmed 3 seconds or more. Under no condition can the yellow clearance interval be manually controlled. It must be timed internally by the controller as per Department specifications.

6. The green interval must display a minimum of 5 seconds before being advanced to the yellow clearance interval.

7. The controller will allow for a variable all red clearance interval from 0 seconds to 999 seconds.

8. Portable traffic control signals will be either manually controlled or traffic actuated. Indicator lights for monitoring the signal operation of each approach will be supplied and visible from within the work zone area.

9. When the portable traffic control signals are radio actuated the following will apply:

a. The transmitter will be FCC Type accepted and not exceed 1 watt output per FCC, Part 90.17. The manufacturer must comply with all "Specific limitations" noted in FCC Part 90.17.

b. The Controller will force the traffic signal to display red toward the traffic approach in case of radio failure or interference.

10. The trailer and supports will be painted construction/maintenance orange enamel in accordance with the MUTCD color.

11. Ensure the certification number is engraved or labeled permanently on equipment.

12. Ensure the device has an external, visible, water resistant label with the following information: "Certification of this device by the Florida Department of Transportation allows for its use in Construction Zones Only".

13. All electronic assemblies shall meet the requirements of NEMA TS-5-2017 Section 4.

990-8 Work Zone Signs.

990-8.1 Post Mounted Sign Supports:

990-8.1.1 General: Provide steel u-channel posts that conform to ASTM A499 Grade 60. For each u-channel post, punch or drill 3/8 inch diameter holes on 1 inch centers through the center of the post, starting approximately 1 inch from the top and extending the full length of the post. Ensure that the weight per foot of a particular manufacturer's post size does not vary more than plus or minus 3.5% of its specified weight per foot. Taper the bottom end of the post for easier installation. Machine straighten the u-channel to a tolerance of 0.4% of the length.

990-8.2 Portable Sign Stands: Provide portable sign stands that meet the requirements of MASH TL-3.

990-8.2.1 Product Application: Manufacturers seeking inclusion on the APL must submit the following:

1. Product Drawing, which at a minimum includes:
   a. Model Number
   b. Sign panel size
   c. Allowable sign panel substrate material
   d. Height to bottom of sign panel
   e. Any field assembly details and technical information necessary for proper application and installation

2. Crash testing reports.
3. All relevant FHWA Eligibility Letters.

990-8.3 Sign Panels: Use signs that meet the material and process requirements of ASTM D4956 and Section 994. Use Type VI sheeting for vinyl signs. Mesh signs must meet the color, daytime luminance, and non-reflective requirements of Section 994, Type VI. Use Type IV sheeting for fluorescent orange work zone signs. Incident management signs shall be Type VI fluorescent pink. Use Type IV and Type XI sheeting for all other work zone signs.

990-9 Temporary Raised Rumble Strips.

990-9.1 General: Temporary raised rumble strips shall meet the physical display and operational requirements in the MUTCD for temporary raised rumble strips and be listed on the APL. The temporary raised rumble strip may be either a removable striping type or a portable type described below:

990-9.1.1 Removable Striping Type:

Table 990-2	
Characteristic	Requirement
Composition:	Removable Polymer Striping Tape with pre-applied adhesive
Color:	White, Black or Orange
Cross-section:	0.25 in. to 0.50 in. (height) x 4 in. (wide)

990-9.1.2 Portable Type:

Table 990-3	
Characteristic	Requirement
Composition:	Molded Engineered Polymer, Steel or Aluminum
Weight	Internally ballasted to a minimum of 100 lbs. to maintain position in use without the use of adhesives or mechanical fasteners
Color:	White, Black or Orange
Shape	Beveled on the leading edge
Cross-section:	0.625 in. to 0.875 in. (height) x 12 in. to 14 in. (wide)

990-10 Temporary Barrier.

Producers of temporary concrete barrier seeking inclusion on the Department's Production Facility Listing shall meet the requirements of Section 105.

Manufacturers seeking evaluation of proprietary temporary barrier systems for inclusion on the APL must meet MASH TL-3 criteria and submit the following:

1. Product drawings, signed and sealed by a Professional Engineer registered in the State of Florida, which at a minimum must include:
   a. Freestanding and anchored details, as appropriate
   b. Section views and tables showing required setback distance (deflection space) for all installation configuration options
   c. Alignment and Length of Need requirements
   d. Transition and overlap details
   e. End treatment details
2. Installation manuals

3. Crash testing reports
4. All relevant FHWA Eligibility Letters

990-11 Temporary Crash Cushion (Redirective or Gating).

Manufacturers seeking evaluation of crash cushions for inclusion on the APL must meet MASH TL-2 or TL-3 criteria and submit the following:

1. Product drawings, signed and sealed by a Professional Engineer registered in the State of Florida, which at a minimum must include:
    a. Anchorage details for both the crash cushion and abutting temporary barrier
    b. Tables showing the relevant system information and lengths for all options
    c. Length of need location
    d. Transition details
    e. List of all components
2. Installation manuals
3. Crash testing reports
4. All relevant FHWA Eligibility Letters

990-12 Truck Mounted Attenuators and Trailer Mounted Attenuators:

Equip truck mounted and trailer mounted attenuator units with lights and reflectors in compliance with applicable Florida motor vehicle laws, including turn signals, dual tail lights, and brake lights. Ensure that lights are visible in both the raised and lowered positions if the unit is capable of being raised.

Install either alternating black with yellow or white with orange sheeting on the rear of trailer mounted attenuators and truck mounted attenuators in both the operating and raised position. Use Type III (work zone) or Type IV sheeting consisting of 4 or 6 inch wide stripes installed to form chevrons that point upward. All sheeting except black must be retroreflective.

Manufacturers seeking evaluation of truck mounted attenuators or trailer mounted attenuators for inclusion on the APL must meet the MASH TL-2 or TL-3 criteria and submit the following:

1. Minimum and maximum support vehicle weights
2. User manuals
3. Crash testing reports
4. All relevant FHWA Eligibility Letters

990-13 Channelizing Devices.

990-13.1 General: Provide channelizing devices in accordance with the MUTCD and the dimensions shown in the Standard Plans.

990-13.2 Product Application: Manufacturers seeking inclusion of channelizing devices on the APL shall submit the following:

1. For Cones, Drums, and Temporary Tubular Markers:
    a. Photographs
    b. Drawings of sufficient detail to distinguish between similar devices
    c. Manufacturer self-certification of MASH compliant
2. For Barricades and Vertical Panels:
    a. Installations Instructions

b. Photographs

c. Drawings (may be included in Installation Instructions) of sufficient detail to distinguish between similar devices

d. Any field assembly details and technical information necessary for proper application and installation

e. Crash testing reports demonstrating the device meets MASH TL-3

f. All relevant FHWA Eligibility Letters

990-14 Pedestrian Longitudinal Channelizing Devices.

990-14.1 General: Provide pedestrian Longitudinal Channelizing Devices (LCDs) in accordance with the MUTCD and the Standard Plans.

990-14.2 Product Application: Manufacturers seeking inclusion of pedestrian LCDs on the APL must submit the following:

1. Installations Instructions
2. Photographs
3. Drawings (may be included in Installations Instructions) of sufficient detail to distinguish between similar devices
4. Any field assembly details and technical information necessary for proper application and installation
5. Crash testing reports demonstrating the device meets MASH TL-3
6. All relevant FHWA Eligibility Letters

990-15 Flagger Equipment.

990-15.1 STOP/SLOW Paddles: Provide STOP/SLOW paddles with rigid handles in accordance with the MUTCD and the Standard Plans.

990-15.1.1 Product Application: Manufacturers seeking inclusion of STOP/SLOW Paddles on the APL must submit the following:

a. Photographs or drawings of sufficient detail to distinguish between similar devices

b. Manufacturer self-certification of MASH compliance

990-16 Portable Temporary Lane Separator.

990-16.1 General: Provide portable temporary lane separator in accordance with the Standard Plans and must come in connectable sections of 36 inches to 48 inches in length.

990-16.2 Product Application: Manufacturers seeking inclusion of portable temporary lane separator on the APL shall submit the following:

1. Installations Instructions
2. Photographs
3. Drawings (may be included in Installation Instructions) of sufficient detail to distinguish between similar devices
4. Any field assembly details and technical information necessary for proper application and installation
5. Crash testing reports demonstrating the device meets MASH TL-3
6. All relevant FHWA Eligibility Letters

990-17 Type III Barricade.

990-17.1 General: Provide type III barricades in accordance with the requirements of the MUTCD and the dimensions shown in the Standard Plans.

990-17.2 Product Application: Manufacturers seeking inclusion of type III barricades on the APL shall submit the following:

1. Installations Instructions
2. Photographs
3. Drawings (may be included in Installation Instructions) of sufficient detail to distinguish between similar devices
4. Any field assembly details and technical information necessary for proper application and installation
5. Crash testing reports demonstrating the device meets MASH TL-3
6. All relevant FHWA Eligibility Letters

SECTION 991
CHANNELIZING DEVICE MATERIALS

991-1 Tubular Markers.

991-1.1 General: This subarticle describes the material requirements for tubular markers installed in accordance with Section 704. All Tubular Marker products shall be listed on the Department's Approved Products List (APL).

991-1.2 Dimensions: The post shall have a minimum diameter of 3 inches. The base of the tubular marker shall have a maximum diameter, width, or length of 8 inches. The height of the tubular marker above the pavement surface shall be 36 inches.

991-1.3 Color: Tubular Marker color must be uniform and integral throughout entire height of the post. The base may be black in color.

991-1.3.1 White: The yellowness index shall not exceed 12, tested in accordance with ASTM E313. The daytime 45 degrees, 0 degrees luminance factor, Cap Y, shall be a minimum of 70, tested in accordance with ASTM E1349.

991-1.3.2 Yellow: The daytime 45 degrees, 0 degrees luminance factor, Cap Y, shall be a minimum of 60, tested in accordance with ASTM E1349.

991-1.4 Retroreflective Sheeting: The color of the retroreflective sheeting shall match the color of the tubular marker. The retroreflective sheeting shall be abrasion resistant Type IV or Type V and meet the requirements of Section 994. The retroreflective sheeting shall meet supplementary requirements for reboundable sheeting as stated in section S.2 of ASTM D4956. The sheeting shall wrap around the entire circumference of the tube and have a minimum vertical dimension of 10 inches. The top of sheeting shall be 1-1/2 inches plus or minus 1/2 inch below the top of post.

991-1.5 Product Testing: Manufacturers seeking evaluation of Tubular Markers not listed on the APL must include test reports from AASHTO Product Evaluation & Audit Solutions documenting the product meets the requirements of this Section. Impact testing must be performed on concrete in accordance with AASHTO Product Evaluation & Audit Solutions: Evaluation of Temporary Traffic Control Devices, Flexible Delineators for the category of High Speed Applications and for hot weather test temperature only.

Impact tests shall be performed only on tubular markers measuring 36 inches above the pavement surface.

Acceptable products are those meeting the following requirements after receiving an average of 45 bumper impacts per sample and an average of 150 tire impacts per sample:

1. All posts shall self-restore to within 15 degrees list or lean from vertical.
2. All posts shall have a minimum of 50% of its cross-section, at any point along the post height, free of tears or cracks.

991-1.6 Approved Product List Submission Requirements: Manufacturers seeking evaluation of Tubular Marker products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation.

Table 991-1	
Documentation	Requirement
Installation Instructions	Include mounting surface preparations, and touch-up and repair procedures. Separate installation instructions are required for different substrates. Identify adhesive types and mechanical anchor types for attachment of base to substrate.
AASHTO Product Evaluation & Audit Solutions: Audit Report	See Section 991-1.5
Product Label Photo	Displays the Product Name. Displays additional label requirements, if needed.
Product Photo	Displays the significant features of the product. Displays location of Manufacturer name and model number.
Technical Data Sheet, marker	Uniquely identifies the product and includes product specifications, storage instructions, and recommended installation materials and equipment as applicable.
Product Sample	Upon request from the Department, submit a sample of the tubular marker mounting material or hardware. If the product is a system comprised of multiple parts, a sample of each part must be submitted.

SECTION 992
HIGHWAY LIGHTING MATERIALS

992-1 General.

992-1.1 Pole Design Criteria: The light poles and bracket arms shall be in accordance with the requirements of the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, the FDOT Structures Manual and with the specific requirements contained in this Section.

992-1.2 Luminaires, Driver, etc.: All luminaires shall be one of the products listed in the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application and sample luminaire in accordance with Section 6.

The light source for luminaires shall be either light emitting diodes (LED), magnetic induction or plasma induction.

The luminaire housing shall be constructed of precision cast aluminum with a corrosive resistant polyester powder coat finish. The standard color shall be gray. The housing shall have an electrical terminal block to attach the luminaire cable and a hinged door which provides direct access to internal parts. Hinged doors are not required for high mast luminaires and underdeck luminaires. All hardware on the exterior of the housing shall be stainless steel. The refractor and lens shall consist of glass or an optical grade polymer. The manufacturer shall place a permanent tag in the luminaire housing imprinted with: the manufacturer name, luminaire voltage, lamp wattage, and provide a blank area for the Contractor to inscribe the installation date.

Luminaires shall meet the following requirements: UL 1598 listed and labeled for installation in wet locations by an OSHA recognized "Nationally Recognized Testing Laboratory" (NRTL), be capable of maintaining 94.1% intensity at 10,000 hours with an ambient temperature of 25°C (IES LM-80) and have IESNA light distribution curves (IES LM-79) by an EPA recognized laboratory.

The driver shall be rated for 100,000 hours and have a power factor greater than or equal to 90% at full load with a total harmonic distortion less than or equal to 20% at full load. The fixture shall accommodate a circuit voltage of 480V.

Luminaires shall be provided with a minimum 10kV/10kA internal surge suppression module meeting UL 1449/ANSI C62.41.2 Category C.

The manufacturer shall submit a five-year non-prorated full warranty on all components of the luminaire to the Department. The warranty shall begin on the project acceptance date and include all components of luminaire.

992-1.3 Conductors: All conductors shall be color-coded stranded copper meeting the requirements of NEMA WC 70. All conductors shall be tested and listed by a NRTL.

Service and circuit conductors shall be single-conductor cable Type THWN-2 and shall not be smaller than No. 6 AWG.

Bonding ground conductor shall have a green jacket and shall not be smaller than No. 6 AWG.

992-1.4 Conduit: Conduit shall meet the requirements of Section 630.

992-1.5 Electrical Ground Rod: The electrical ground rods shall be 5/8 inch copper clad steel. Electrical ground rods shall be sectional type where length exceeds 10 feet.

992-1.6 Fittings and Bends: Fittings, bends and miscellaneous hardware shall be in accordance with the National Electrical Code (NEC) and shall be compatible with the adjacent conduit and materials.

992-1.7 Conductor Splices: Unless otherwise shown in the Standard Plans or authorized by the Engineer, splices shall be made with compression sleeves or split bolt connectors. The connector shall be sealed in silicone gel that easily peels away leaving a clean connection. The gel shall be contained in a UV, impact, and abrasion resistant closure that when snapped around the split bolt will provide a waterproof connection without the use of tools or taping.

992-1.8 Pull Boxes: Pull boxes shall meet the requirements of Section 635.

992-1.9 Distribution Service Point Equipment: All electrical equipment shall be provided with 75°C terminal lug connectors.

992-1.9.1 Service Main: Two pole 480 V, 35,000 min. AIC, solid neutral, NEMA 4X stainless steel, enclosed circuit breaker rated for service entrance.

992-1.9.2 Control Panel Enclosure: NEMA 4X stainless steel enclosure ground mounted in accordance with Standard Plans, Index 639-002. Dimensions shall be as necessary for equipment inside.

992-1.9.3 Control Panel Main Disconnect: Two Pole, 480V, 35,000 AIC with solid neutral in NEMA 1 enclosure. Number and rating of branch circuit breakers shall be as indicated in Plans.

992-1.9.4 Lighting Contactor: Two pole, 480V electrical contactor in NEMA 1 enclosure w/HOA on cover, 120V coil and fused control power transformer.

992-1.9.5 Electrical Panel: Single Phase (two pole), 480V, with solid neutral in NEMA 1 enclosure.

992-1.9.6 Surge Protection Device: Type 1, UL or NRTL listed to 1449, Third Edition. Surge current rating on per phase basis shall equal or exceed 50kA. I-nominal rating shall be 10kA or 20kA. 480V true single phase system modes of protection shall include L-G and N-G having UL 1449-3 Voltage Protection Ratings of 2000V or lower. 240/480V split phase systems deriving 480V across two energized conductor's modes of protection shall include L-G and N-G having UL 1449-3 Voltage Protection Ratings of 1200V or lower.

992-2 Conventional Lighting.

992-2.1 Poles: Poles for conventional lighting shall be aluminum unless otherwise shown in the Plans.

992-2.1.1 Aluminum Poles: Aluminum poles shall be round, one piece, continuous-tapered high-strength aluminum, and of an approved alloy meeting the requirements of the Standard Plans. The poles shall be of such length as to provide the approximate luminaire mounting height shown in the Plans. Poles installed on bridges, walls and median concrete barriers shall be equipped with internal vibration damping devices.

992-2.1.2 Concrete Poles: Concrete poles may be used only when specified in the Plans. When specified, concrete poles shall meet the requirements of Section 641 and Standard Plans, Index 641-010 for a Type P-III pole.

992-2.2 Bases: Aluminum poles shall be installed on transformer bases with the exception of lights installed on bridge pilasters or on top of median concrete barriers. Transformer base poles shall have a grounding lug in the transformer base. The base shall be arranged for anchoring to a transformer base with four 1 inch anchor bolts (minimum size).

992-2.3 Bracket Arms: Bracket arms shall be aluminum, truss-type construction, consisting of upper and lower members with vertical struts, and shall have the luminaire end

formed to accommodate a 2 inch pipe slipfitter. The bracket arms shall meet the design requirements of 992-1.1. Bracket arms shall be attached to aluminum poles, with machine bolts and pole adapters, unless approved otherwise.

992-2.4 Luminaires: Provide luminaires in accordance with the following requirements.

992-2.4.1 Luminaires for Conventional Lighting: Luminaires shall meet the following additional requirements:

a. A maximum correlated color temperature (CCT) of 4000°K meeting ANSI C78.377A (3985°K, plus or minus 275°K).

b. The optical portion of the housing shall be sealed to provide an IP 66 rating.

The luminaire mounting assembly shall be a slipfitter type designed to accommodate a nominal 2 inch pipe size (2-3/8 inch O.D.) arm or a pole top mounting assembly designed to accommodate a 2-3/8 inch pole top tenon.

For APL qualification, the manufacturer must have a fixture with an IESNA light distribution curve (IES LM-79) by an EPA recognized laboratory, meeting a minimum pole spacing of 240 feet using the AGi32 lighting optimization tool with the following settings:

Table 992-1

Setting	Requirement
Roadway Standard	IES RP-8-18
R-Table	R3 (Q0=0.07)
Roadway Layout	Two Rows Opposite, With Median, 2R OPP w/M
Roadway Width	40 feet
Median Width	22 feet
Number of Lanes in Direction of Travel	3
Driver's Side of Roadway	Right
Calculation Area	Bottom
Mounting Height	As per manufacturer's recommendation
Setback	12 feet
Tilt	0°
Optimization Criteria	Avg. Illuminance = 1.5 fc Avg./Min. Ratio = 4 Max./Min. Ratio= 10 Lv Max./L Avg. Ratio= 0.3
Arm Length	Pole top fixtures – as provided by the IES file Arm mounted fixtures – 12 feet

992-2.4.2 Luminaires for Wildlife-Sensitive Conventional Lighting: Luminaires must meet the following additional requirements:

a. The light source for the luminaires must be true red, orange, or amber light-emitting diodes (LEDs) with no more than 1.75% of the spectral power distribution below 560 nm. Submit testing report.

b. The optics must have an IP 66 rating. Submit testing report.

c. The luminaire mounting assembly must be a slipfitter type designed to accommodate a nominal 2 inch pipe size (2-3/8 inch O.D.) arm or a pole top mounting assembly designed to accommodate a 2-3/8 inch pole top tenon.

d. Luminaires must have a IESNA light distribution curve (IES LM-79) designated by an EPA-recognized laboratory. Submit testing report.

e. Luminaires must meet a minimum pole spacing of 50 feet using the AGi32 lighting optimization tool in accordance with the settings shown in 992-2.4. Submit IES file.

992-2.5 Luminaire Cable: Pole and bracket cable shall be multi-conductor Type XHHW-2 XLP TC with three No. 10 AWG wires. The ground wire must have green-colored insulation.

992-2.6 In Line Fuse Holders: In line fuse holders shall provide a breakaway connection and be UL recognized per Guide IZLT2 and rated for 600V. The wire connections in the fuse holders shall be a copper or equivalent type setscrew. Fused connections shall utilize an ATQ or FNQ 10 amp time delay fuse rated for 500V. Fuses shall be UL listed to Standard 248-14. The rating for the fuse holders shall be water resistant or submersible rated.

992-2.7 Surge Protection Devices for Circuit Protection at Poles: The metal oxide varistor (MOV) based SPD shall be potted in a manner to be waterproof. UL listing is not required. SPD's per mode surge current rating shall be 20kA for 480V to ground and 20kA for neutral to ground. Maximum continuous operation voltage (MCOV) shall be not less than 550Vrms and not greater than 600Vrms. All wires and internal spacings shall be insulated for 600Vrms.

992-2.8 Pole Cable Distribution System:

992-2.8.1 General: These requirements are applicable for all systems rated up to and including 600V. The installed system shall be in compliance with Standard Plans, Index 715-001.

Systems installed as alternates to the Standard Plans shall be one of the products listed on the APL. Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

Alternate Systems shall meet the following requirements:

A modular color coded cable system consisting of rubber cords with integrally molded watertight submersible connectors, inline fuses, submersible surge arrestor and breakaway connectors shall be installed. The cables shall extend from an underground pull box near the base of the pole to the luminaires at the top of the pole. A cable system shall be required at each pole.

The cable system shall consist of the following described components:

1. Distribution Block: The red molded body shall contain a three wire female outlet integrally molded to a 24 inch length of 10/3 SOOW cable with an end molded to the body and the other end shall be spliced in the field to the distribution cable that feeds through the underground pull box near the base of the pole. The block shall be watertight and submersible when the integrally fused plug on the power cable is engaged and fully seated. Dimensions shall be approximately 2 inches by 3 inches by 3 inches. The size is important because of limited space.

2. Surge Arrestor Cable: Provide a 12 inch length of 10/2 SOOW cable with a red male plug to match the red female connector cable extending from the fused plug on the power cable. The other end of the surge arrestor cable shall be integrally molded to a

MOV waterproof surge arrestor. The red male plug shall make a submersible connection when mated to the red female connector on the power cable. A separate 12 inch length of No. 10 THWN green ground wire shall be provided from the surge arrestor to attach to the ground system in the pull box.

3. Power Cable: This cable feeds the luminaire cable and the surge arrestor cable from the load side of its integrally fused red male plug end. The red fused plug shall contain 10A 500V fuses (13/32 inch by 1-1/2 inch) or equal. The fuse holder manufacturer's suggested slug (blank or dummy fuse) must be installed on the neutral side for line to neutral service. Both lines shall be fused for line to line service. The section that feeds the luminaire cable shall be a 10 foot section of 10/3 SOOW cable with an orange female connector molded to the end extending up into the base of the pole. This female connector shall pass easily through a standard size 1-1/4 inch PVC elbow and make a submersible connection when mated with the orange male plug on the luminaire cable. The section that feeds the surge arrestor cable shall be 12 inches in length of 10/2 SOOW cable with a red female connector on the end. The red female connector shall make a submersible connection when mated to the red male plug on the surge arrestor cable.

4. Luminaire Cable: This cable is Type XHHW-2 XLP-TC with three No. 10 AWG an orange male molded plug molded to match the orange female end of the power cable. The connector shall require 25 pounds of force to mate or disengage from the female end. When engaged the connection shall be watertight and submersible. The cable strain relief shall extend approximately 2 inches from the connector.

The distribution block and each connector shall be made of thermosetting synthetic polymer which is non-flame supporting and which remains flexible over a temperature range of minus40°F to plus 190°F. Hardness of the molded rubber shall be 65 durometer.

992-2.8.2 Testing and Performance Criteria: The system shall pass the following performance criteria in accordance with NEC 110 2.

1. Dielectric Test: No breakdown shall occur with a test potential of 1,960V applied between the primary conductors (tied together) and the protective ground for a period of one-minute.

2. Leakage Current Test: Leakage current shall be measured on the mated connectors between the primary conductors and the protective ground conductor. When tested at the rated operating voltage, the leakage current shall not exceed 0.5 mA. The mated connectors shall then be wrapped in aluminum foil and the leakage current measured between the primary conductors and the foil wrap. When tested at the rated operation voltage the leakage current shall not exceed 0.5 mA.

3. Flame Retardant Test: Flammability tests shall be conducted on the cable, the molded body of the connectors, and the molded protective caps. These materials shall be subjected to five flame application, on for 15 seconds and off for 15 seconds. The materials shall self-extinguish within one minute upon removal of the flame and not burn through.

4. Internal Temperature Test: The internal temperature rise of the contact area of the mated connectors shall not exceed a temperature rise of 54°F referenced to 73°F ambient temperature when operated at the maximum current rating.

5. External Temperature Test: The external temperature rise of the mated connectors and the cable shall not be greater than 54°F referenced to 73°F ambient temperature when operated at the maximum current rating.

6. Fault Test: The mated connectors shall be fault tested by applying a test current of 1,000A, 60 Hz for a minimum of 3 cycles (50 ms). The mated connectors shall then satisfactorily pass the dielectric test.

7. Drop Test: The connectors shall not break, crack or suffer other damage when subjected to eight consecutive drop tests from 3 feet above the concrete floor with the connectors having been rotated 45 degrees between each drop.

8. Crushing Test: No breakage of deformation shall result when the mated and unmated connectors are subjected to a crushing force of 500 pounds for one minute. Following the crush test, the dielectric test shall be satisfactorily passed.

9. Impact Test: No breakage or deformation shall result when the connectors are subjected to an impact caused by dropping a cylindrical 10 pound weight having a flat face 2 inches in diameter from a height of 18 inches.

10. Flex Test: No detachment or loosening shall result when each connector is subjected to a 5,000 cycle flex test at the cable/bond area back and forth in a plane through an angle of 180 degrees. Following the flex test the dielectric test shall be satisfactorily passed.

11. No Load Endurance Test: No excessive wear shall result when the male and female connectors and protective cap and female connector were subjected to 2,000 cycles of complete insertion and withdrawal.

12. Rain Test: The mated and capped connectors shall be subjected to a continuous water spray (simulating worst case outdoor rain down pour) for at least one hour at a rate of at least 18 inches per hour at an operating pressure of 5 psi. The dielectric and leakage current tests shall be satisfactorily passed. The connectors shall be unmated and caps removed. Inspection shall indicate that water had been successfully prevented from reaching the contact areas of the connectors.

13. Watertight (Immersion) Test: The mated and capped connectors shall be immersed in water for one hour in which the highest point of the test samples in as least 3 feet below the water level. Immediately following the immersion, a satisfactory dielectric and leakage current tests shall be performed. The connectors shall be unmated and caps removed. Inspection shall indicate that water had been successfully prevented from reaching the contact areas of the connectors.

14. Exposure to Deteriorating Liquids: The cable and connectors shall be dried at 212°F for one hour. The samples shall then be immersed in ASTM Reference Oil No. l and ASTM Reference Fuel C liquids for one hour. The samples shall show no evidence of bubbling, cracking or corrosion. Within one hour after being removed from the fluids, the test samples shall satisfactorily pass the flammability test.

992-3 High Mast Lighting.

992-3.1 Poles: Poles for high mast lighting shall be galvanized steel unless otherwise shown in the Plans. Steel high mast poles shall be continuous-tapered, round or minimum of 12 sided poles and meet the requirements of the Standard Plans.

Each pole shall include a galvanized steel winch plate of sufficient size to mount the winch, portable drive unit mounting tube, circuit breaker panel and surge arrestor.

992-3.2 Luminaires: The luminaires shall meet the following requirements.

a. A maximum correlated color temperature (CCT) of 4000°K meeting ANSI C78.377A (3985°K, plus or minus 275°K).

b. The optical portion of the housing shall be sealed to provide an IP 66 rating.

The luminaire mounting assembly shall be a slip fitter type designed to accommodate a nominal 2 inch pipe size (2-3/8 inch O.D.) connection. For qualification, the manufacturer must have a fixture with a Type V IESNA light distribution curve (IES LM-79) by an EPA recognized laboratory, capable of providing photometrics similar to a 1000 W HPS fixture when mounted on 80 to 120 foot poles.

992-3.3 Surge Protective Devices for Surge Protection at Poles: Surge protective devices (SPD) shall be Type 1 or Type 2. UL or NRTL listed to UL 1449 Third Edition. Surge current rating on a per phase basis shall be equal or exceed 50kA. I-nominal rating shall be 10kA or 20kA. Modes of protection shall include L-G and N-G having UL 1449-3 Voltage Protection Ratings (VPR's) of 2000V or lower.

992-3.4 Lowering System: The lowering system may be either a top latch or bottom latch system. The lowering system shall consist of the following.

992-3.4.1 Head frame and Covers: The head frame unit shall rigidly mate the top of the pole to the head frame platform. The platform with its associated sheaves shall be covered to prevent water from entering the top of the pole. The head frame structure shall be stainless steel and attach to the pole by stainless steel bolts or by means of a galvanized steel slipfitter. The head frame shall utilize two stainless steel cable sheaves for each lowering cable. The cable sheaves shall be a minimum of 5 inches in diameter and grooved to the exact cable diameter, for 180 cable bearing surface. The power cord shall travel on sheaves or a combination of rollers providing a radius for the cord of 6 inches or larger. Each end of the sheaves or rollers shall have a keeper to prevent the cable from jumping out of the roller track or sheave cover that will act as a keeper. Bearings shall have permanent lubrication. For top latch systems the head frame shall include latch mechanisms which support the luminaire ring in the latched position and prevent the luminaire ring from rotation. For bottom latch systems the head frame shall include centering guides which center the luminaire ring and prevent the ring from rotation.

992-3.4.2 Luminaire Ring: The luminaire ring assembly shall consist of the luminaire ring, hoisting cable terminator tubes, and weather proof junction box. The luminaire ring and the junction box shall be fabricated of stainless steel. The ring shall be supplied with bolt on 2 inch stainless steel pipe tenons for the required number of luminaires. Two of the stainless steel tenons shall have a 1 inch half coupling welded to the tenon for the possible installation of Federal Aviation Administration (FAA) approved obstruction lights. The inner portion of the ring shall be equipped with a PVC shock absorbing tubes or shall utilize roller contact spring-loaded centering arms which center the luminaire ring and protect the pole and luminaire ring during raising or lowering operations. A 600 volt terminal block, completely prewired shall be included in the junction box. The luminaire ring shall be prewired with distribution wiring suitable for proper application and operation of the luminaires. A male flanged receptacle shall be mounted on the luminaire ring to allow testing of the luminaire while in the lowered position. The receptacle shall face away from the pole for easy access.

992-3.4.3 Lowering Cables: For bottom latch lowering systems, a minimum of two cables shall be used to lower the luminaire ring. Lowering cables for bottom latch systems shall be stainless steel aircraft cables of 1/4 inch or greater diameter. Where the wire cables bend over sheaves or the winch drum, the maximum working stress in the outer fibers of wire cable shall not exceed 20% of the cable manufacture's rated ultimate stress. The hoisting cable shall manually latch at the base of the pole and shall remove the load from the winch system. Each latch point shall be capable of supporting the entire weight of the luminaire ring assembly

including luminaires. All moving parts of the latch mechanism shall be within reach from the ground level.

For top latch lowering systems, three stainless steel aircraft cables of 3/16 inches or greater diameter shall be provided. The transition yoke, hardware connecting the lowering cables to the transition yoke and hardware connecting the winch cable to the transition yoke shall be stainless steel. Where the wire cables bend over sheaves or the winch drum, the maximum working stress in the outer fibers of wire cable shall not exceed 20% of the cable manufacturer's rated ultimate stress. All latching systems shall remove the load from the winch system. Each latch point shall be capable of supporting the entire weight of the luminaire ring assembly including luminaires.

992-3.4.4 Modular Power Cable System: The modular cable system shall consist of cables with weathertight connectors. All portions of the cable system shall be rated up to and including 600 V. The plugs and connectors shall be UL or NRTL listed to UL 498 twist-lock type devices with a NEMA L16-30R configuration for 480V line to neutral systems or for 480V line to line systems. The X designated prong shall be the hot leg for 480V line to neutral systems. The X and Z designated prongs shall be the hot legs for 480V line to line systems. The Z designated prong shall always be treated as a neutral leg. The plugs and connectors shall be equipped with watertight safety shrouds meeting UL 4X enclosure rating. Plugs and connectors when used on cord sets shall be equipped with IP 55 rated waterproof boots.

The power cable shall be a minimum of 10/3 SOOW cable that is wired from distribution cable in the pull box near the base of the pole to the line side of the circuit breaker panel.

The circuit breaker cable shall be an 8 foot length of 10/3 SOOW (minimum) cable that is connected to the load side of the circuit breaker panel and a female receptacle on the other end. This female receptacle shall mate with the male plug on the pole cable, the male flanged receptacle on the luminaire ring and the male plug on the portable step-down transformer.

The pole cable shall be the length of the mounting height of the pole plus 6 feet. The cable shall be a minimum of 10/3 SOOW with a male plug on one end that mates with the female receptacle on the circuit breaker cable. The other end fits under the lugs in the junction box on the luminaire ring. The power cable shall be attached to the luminaire ring with a stainless steel strain relief Kellem's grip capable of withstanding the pull of the weight of the cable. All power cables should be attached to the stainless steel weathertight wiring chamber with weathertight cable connectors

992-3.4.5 Winch Drum: The drum shall be constructed of stainless steel and be designed to provide a level wind of wire cable. The winch shall be a reversible worm gear self locking type with an integral friction drag brake to prevent free spooling. Raising speed of the luminaire ring shall be a minimum of 12 feet per minute. Stainless steel 7 x 19 aircraft cables of 1/4 inch or greater diameter shall be supplied on the winch. The winch drums shall be designed to provide smooth winding of the winch cables on the drum and to prevent cable slippage on the drum.

992-3.4.6 External Portable Winch Motor (One per Project): The winch shall be designed for hand operation or for operation by means of a 1/2 inch heavy duty reversing electric drill motor or a portable reversible AC motor with a magnetic brake. Both portable power units shall be mounted to the winch by a stainless steel mounting bracket and shall be

remote controlled to enable the operator to stand 25 feet from the pole. One portable drill motor or portable motor power unit shall be provided for each project.

992-3.4.7 Portable Step-Down Transformer (One per Project): A portable 1.5 kVA dry type transformer shall be provided for each project. The transformer shall step-down the high mast distribution voltage to 120/240V. The transformer shall be mounted in a NEMA 3R enclosure and have a male plug or receptacle which mates to circuit power cable. The transformer shall also have a 120V grounded receptacle for use by electric drill motor or portable motor power unit.

992-4 Sign Lighting.

992-4.1 Luminaires: The luminaires shall meet the following requirements.

a. A maximum correlated color temperature (CCT) of 5000°K meeting ANSI C78.377A (5028°K, plus or minus 283°K).

b. The optical portion of the housing shall be sealed to provide an IP 66 rating.

The luminaire mounting assembly for a sign luminaire shall be a slipfitter type designed to accommodate a 1-1/2 inch, Schedule 40 steel pipe arm connection.

992-5 Underdeck Lighting.

992-5.1 Luminaires: The luminaires shall meet the following requirements.

a. A maximum correlated color temperature (CCT) of 4000°K meeting ANSI C78.377A (3985°K, plus or minus 275°K).

b. The optical portion of the housing shall be sealed to provide an IP 55 rating.

Underdeck fixtures shall be wall mounted fixtures.

992-5.2 Conductors: Underdeck structure lighting conductors shall be Type RHW or THW and shall not be smaller than No. 10 AWG.

992-6 Protection of Light Poles.

Each metal pole shall be appropriately and adequately protected by “tire wrapping” with heavy paper, or by some other effective means, so that no chipping, gouging, or other significant surface damage will be incurred during transit or installation. The poles, when installed, shall be clean and uniformly free from dark streaks and discoloration.

992-7 Luminaire Retrofit Kits for Conventional Lighting.

Luminaire retrofit kits shall meet the following requirements:

a. The light source for luminaire retrofit kits shall be light emitting diodes (LEDs) meeting ANSI C78.377A with a maximum correlated color temperature of 4000ºK (3985ºK ± 275ºK).

b. The luminaire retrofit kit shall be UL 1598C listed by an OSHA “Nationally Recognized Testing Laboratory” (NRTL).

c. The optics shall have an IP 66 rating. Submit testing report.

d. LEDs shall be capable of maintaining 94.1% intensity at 10,000 hours with an ambient temperature of 25°C (IES LM-80). Submit testing report.

e. Luminaire retrofit kits shall have a IESNA light distribution curve (IES LM-79) designated by an EPA-recognized laboratory. Submit testing report.

f. Luminaire retrofit kits shall meet a minimum pole spacing of 240 feet using the AGi32 lighting optimization tool in accordance with the settings shown in Sub-article 992-2.4. Submit IES file.

g. Luminaire retrofit kits shall have a driver rated for 100,000 hours with a power factor greater than or equal to 90% at full load and a total harmonic distortion less than or equal to 20% at full load. Submit driver information that documents these requirements, including the operational temperature of the driver at 25ºC.

h. Luminaire retrofit kits shall accommodate a circuit voltage of 480V.

i. Luminaire retrofit kits shall be provided with a minimum 10kV/10kA internal surge protection device (SPD) meeting UL 1449 and ANSI C62.41.2 Category C High. Submit SPD information that documents these requirements.

j. The manufacturer shall submit a five-year non-prorated full warranty on all components of the luminaire retrofit kit to the Department. The warranty shall begin on the project acceptance date and include all components of the luminaire retrofit kit.

SECTION 993
DELINEATORS

993-1 Description.

This section specifies the material requirements for flexible post delineators and barrier delineators.

993-2 Approved Product List.

All flexible post and barrier delineators shall be one of the products listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation. A separate application must be submitted for each product to be evaluated, showing that the product meets the applicable requirements.

Table 993-1
Submittal Compliance Requirements

Documentation	Requirements
Installation Instructions	Surface preparation and installation procedures
Label	Displays the name of the manufacturer, Name of product, APL number,
AASHTO Product Evaluation & Audit Solutions Test Report	For flexible post delineators: AASHTO Product Evaluation & Audit Solutions Evaluation of Temporary Traffic Control Devices- Flexible Delineators, for the proposed mounting category
Product Photo	Displays the significant features of the product and product packaging.
Technical Data Sheet	a. Uniquely identifies the product, b. Product specifications, c. Installation materials and equipment. d. Surface preparation

993-3 Flexible Post Delineators.

993-3.1 Dimensions: The post shall have a minimum width of 3 inches facing traffic and of such length to generally provide a height of 48 inches above the pavement surface.

993-3.2 Color: The post shall be opaque white. The yellowness index shall not exceed 12 when tested in accordance with ASTM E313. The daytime 45 degrees, 0 degrees luminance factor, Cap Y, shall be a minimum of 70, tested in accordance with ASTM E1349.

993-3.3 Retroreflective Sheeting: The reflective sheeting shall be Types IV, V, or XI and meet the requirements of Section 994. The reflective sheeting shall have a minimum width of 3 inches and have a minimum area of 30 square inches.

993-3.4 Impact Performance: Six of the eight posts shall be capable of returning to a vertical position plus or minus 10 degrees with no delaminating. No post shall split, crack, break, or separate from base. Posts shall be tested and evaluated according to the AASHTO Product Evaluation & Audit Solutions Evaluation of Temporary Traffic Control Devices: Flexible Delineators, for the following categories:

993-3.4.1 Pavement/Surface Mounted: Use the Metropolitan Delineator Applications category for Hot Weather with a minimum of 10 impacts (default testing procedure uses a maximum of 200 impacts).

993-3.4.2 Ground Mounted: Use the Ground Mount Side of Roadway Applications category for Hot Weather (default testing procedure uses a maximum of 10 impacts).

993-4 Barrier Delineators.

993-4.1 General: Barrier delineators shall consist of retroreflective sheeting permanently adhered to 0.090-inch minimum thick body. The body shall have a flexible hinge which allows the reflector to fold down and spring back to an upright position after impact. Barrier delineators for guardrail shall be designed for mounting to the web of steel posts or designed for mounting to the top of wood posts. Barrier delineators for concrete barrier, traffic railings, and vehicular longitudinal channelizing devices (LCDs) shall be designed for mounting to the top of barrier.

993-4.2 Retroreflective Sheeting: The sheeting for barrier delineators shall be Type IV or XI meeting the requirements of Section 994. The sheeting shall be yellow or white, depending on the locations of use for each. The dimensions of the retroreflective sheeting shall be a minimum of 3 inches wide by 4 inches high. The sheeting shall be installed by the delineator manufacturer. Delineators for use on median barriers must have yellow sheeting on both sides.

SECTION 994
RETROREFLECTIVE AND NONREFLECTIVE SHEETING AND SIGN PANEL FABRICATION

994-1 Description.

994-1.1 General: This Section specifies the requirements for retroreflective and nonreflective sheeting and sign panel materials and fabrication. This includes the sign sheeting materials such as transparent and opaque process inks for retroreflective sheeting materials, vinyl and transparent overlays.

994-2 Retroreflective and Nonreflective Sheeting Systems.

994-2.1 Materials: Retroreflective sheeting material shall be classified in accordance with and meet the requirements of ASTM D4956. Overlay materials include colored and colorless transparent overlays (to provide UV protection) and vinyl. Inks include transparent and opaque silkscreen inks as well as inkjet inks used in digital print systems.

994-2.2 Approved Product List (APL): All sheeting, process inks and overlay materials shall be listed as a system on the Department's Approved Product List (APL). Sign sheeting systems shall consist of base sheeting with ink and/or overlay materials. Products with an ASTM classification of Type XI or greater will not be accepted for qualification on the APL for fluorescent orange. Manufacturers seeking evaluation of their products need to submit product data sheets, performance test reports from an independent laboratory showing the sign sheeting system meets the requirements of this Section, and APL application in accordance with Section 6. Information on the APL application shall include the individual materials comprising the sign sheeting system and identify colors, ASTM base sheeting classification, adhesive backing class, availability of transparent and/or opaque backing and availability of liner types.

994-2.3 Performance Requirements:

994-2.3.1 General: Sheeting, process inks and overlay materials shall be tested in accordance with, and meet all the performance requirements of ASTM D4956, including Supplemental Requirement S2, Reboundable Sheeting Requirements, except as amended in this Section.

For performance requirements that are color dependent, each color included in the APL application shall be tested and meet the requirements identified in ASTM D4956 or this Section as applicable. All sign sheeting systems consisting of inks and/or overlays will be tested as a system consisting of white base sheeting and each color of ink and/or overlay.

Panels for testing sheeting shall be prepared in accordance with 994-3 for testing. The in-service life for the sign sheeting system shall equal the life of the reflective base sheeting of the system.

994-2.3.2 Retroreflective Intensity: The retroreflectivity of sheeting and sheeting systems shall meet the minimum initial requirements as stated for all observation and entrance angles as identified in ASTM D4956. The 0.2 and 0.5 degree observation angles with an entrance angle of minus 4 degrees per ASTM D4956 shall be used for in-service requirements.

Rotational sensitivity shall be tested in accordance with AASHTO M268. Rotationally sensitive sheeting will be noted on the APL.

994-2.3.3 Clear Overlay Films: Clear overlay film shall be compatible with the sign sheeting system and not delaminate or discolor for the in-service life of the system.

994-2.3.4 Outdoor Weathering: Outdoor weathering exposure of sign sheeting systems shall be performed in accordance with ASTM D4956, and meet the requirements for each system, color, and classification. All testing shall be conducted at an exposure location meeting the Tropical Summer Rain Climate Type (Miami, Florida or equivalent). Outdoor weathering is not required for Type VI fluorescent pink.

994-2.3.5 Packaging and Labeling: Packaging and labeling shall meet the requirements of ASTM D4956.

994-2.3.6 Samples: Field samples shall be obtained in accordance with the Department's Sampling, Testing and Reporting Guide Schedule and on a random basis at the discretion of the Engineer.

994-3 Sign Panels.

994-3.1 Materials: For aluminum sheets and plates for sign panels, meet the requirements of ASTM B 209, Aluminum Association Alloy 6061-T6, 5154-H38 or 5052-H38 and those shown in the Plans.

994-3.2 Preparation of Sign Blanks:

994-3.2.1 De-greasing and Etching for Aluminum Sign Blanks:

994-3.2.1.1 General: Prior to the application of retroreflective sheeting, use any of the methods shown below to de-grease and etch the aluminum sign blanks.

994-3.2.1.2 Hand Method: Under this method, de-grease and etch the blanks in one operation, using steel wool (medium grade) with any of the following combinations of materials:

1. An abrasive cleanser of a commercial grade kitchen scouring powder.
2. Acid and a suitable detergent solution.
3. An alkaline solution.

Thoroughly rinse the blanks with clean water following all hand de-greasing operations.

994-3.2.1.3 Power-Washer Method: Under this method, de-grease the blanks with an inhibited alkaline cleanser, by spraying for 90 seconds with the solution between 135 and 249ºF, the exact temperature to be as recommended by the manufacturer of the cleanser. After the spraying, rinse the blanks with clean water. Then etch the blanks by immersing them in a 6 to 8% solution of phosphoric acid at a temperature of 100 to 180ºF for 60 seconds. After immersion, rinse the blanks in clean water.

994-3.2.1.4 Immersion Method: Under this method, de-grease the blanks by immersing them in a solution of inhibited alkaline cleanser at a temperature between 160 and 180ºF for three to five minutes, and then rinsing with clean water. Then etch blanks by immersing them in a 6 to 8% solution of phosphoric acid at a temperature of 100ºF for three minutes. After immersion, rinse the blanks in clean water.

994-3.2.1.5 Vapor De-greasing Method: Under this method, de-grease the blanks by totally immersing them in a saturated vapor of trichloroethylene. Remove trademark printing with lacquer thinner or a controlled alkaline cleaning system.

994-3.2.1.6 Alkaline De-greasing Method: De-grease the blanks by totally immersing them in a tank containing an alkaline solution, controlled and titrated in accordance with the solution manufacturer's directions. Adapt immersion time to the amount of soil present and the thickness of the metal. After immersion, thoroughly rinse the blanks with running water.

994-3.2.1.7 Etching Method when De-greasing is Separate Operation: If using either of the de-greasing methods described in this section, accomplish etching by one of the following alternate methods:

1. Acid Etch: Etch well in a 6 to 8% phosphoric acid solution at 100ºF, or in a proprietary acid etching solution. Rinse thoroughly with running cold water, which may be followed by a hot water rinse.

2. Alkaline Etch: Etch aluminum surfaces in an alkaline etching material that is controlled by titration. Meet the time, temperature, and concentration requirements specified by the solution manufacturer. After completing etching is complete, rinse the panel thoroughly.

994-3.2.1.8 Chromate Coating: Before applying retroreflective sheeting to the aluminum, treat the aluminum sign surfaces with chromate conversion coating. Coating may consist of an organic or inorganic chromate material. Coatings shall be applied according to the manufacturer's instructions and shall conform to ASTM B449, Class 2.

994-3.3 Drying: Dry the panels using a forced-air drier. Use a device or clean canvas gloves, to handle the material between all cleaning and etching operations and the application of retroreflective sheeting. Do not allow the metal to come in contact with greases, oils or other contaminants prior to the application of retroreflective sheeting.

994-3.4 Fabrication of Sign Blanks: Fabricate all metal parts to ensure a proper fit of all sign components. Complete all fabrication, with the exception of cutting and punching of holes, prior to metal de-greasing and applying the retroreflective sheeting. Cut metal panels to size and shape and keep free of buckles, warp, dents, burrs, and defects resulting from fabrication. Use aluminum sheets with increments of 4 feet in width; except, for sign widths that are not multiples of 4 feet. A maximum of two panels may be cut to less than 4 feet, and no panel may be cut to less than one foot. Mount aluminum sheets vertically and provide backing strips at vertical joints to keep the abutting sheets in proper alignment.

Ship all multi-panel signs to the project intact, completely assembled and ready to be installed. Fabricate signs taller than 10 feet as two separate signs with a horizontal splice, ready to be spliced and installed.

994-3.5 Fabrication of Retroreflective Sign Faces:

994-3.5.1 General: Fabricate signs with sign sheeting systems listed on the APL meeting the requirements in Section 700, the Standard Plans and the Plans.

994-3.5.2 Application of Sheeting: Apply retroreflective sheeting to the base panels with mechanical equipment in a manner specified for the manufacture of traffic control signs by the sheeting manufacturer. For sheeting that has been identified as rotationally sensitive, apply white sheeting for cut-out legends, symbols, borders and route marker attachments within the parent sign face at the optimum rotation angle according to the identification markings. Apply all background sheeting at a uniform rotational angle. The retroreflective sheeting for each sign will be from the same roll or LOT number. Apply consecutively alternate successive width sections of either sheeting or panels to ensure that corresponding edges of sheeting lie adjacent on the finished sign. If the sign cannot be constructed from retroreflective sheeting from the same roll or LOT number, the fabricator may color match from a different LOT; the color between the rolls cannot exceed three ΔE's using test method ASTM D 2244. The Engineer shall not accept nonconformance that may result in non-uniform shading and an undesirable contrast between adjacent widths of applied sheeting or non-optimum retroreflectivity in the finished sign and installation.

Sheeting is to be trimmed at 45-degree angle from the edge of each panel. Finish signs by sealing sheeting splices and sign edges according to sign manufacturer recommendations.

994-3.5.3 Direct and Reverse Screen Processing: Screen message and borders on retroreflective sheeting in accordance with the recommendations of the ink or overlay manufacturer. Process messages either before or after applying the sheeting to the base panels.

The transparent and opaque process inks furnished for direct and reverse screen processing shall be of a type and quality formulated for retroreflective sheeting materials as listed on the APL and applied in accordance with the manufacturer's instruction. Screen processing in accordance with the techniques and procedures recommended by the manufacturer shall produce a uniform legend of continuous stroke width of either transparent or opaque ink, with sharply defined edges and without blemishes on the sign background that will affect the intended sign use.

994-3.5.4 Digital Printing Process: Digital print systems shall include a digital printer, with appropriate software and drivers, flexible white or colored prismatic retroreflective sheeting with colorless overlay in accordance with the recommendation of the sheeting manufacturer. The use of a certified digital sign fabricator will be required. Digital sign fabricators shall be certified by the reflective sheeting manufacturer or a third-party certifier approved by the reflective sheeting manufacturer. Inks or ribbons shall be of a type and quality formulated to produce colors that meet the chromaticity requirements given in ASTM D4956 for retroreflective sheeting material when printed and finished as recommended by the sheeting manufacturer.

994-3.5.5 Finished Sign Face: Provide finished signs with properly aligned clean cut and sharp messages and borders. Fabricated signs shall be free of wrinkles, bubbles, foreign matter, scratches, free of patches, or other visually identifiable defects. Ensure that finished background panels are essentially a plane surface.

994-3.5.6 Packaging and Labeling: For permanent roadway signs, label the back of all finished panels at the bottom edge with "FDOT", the date of fabrication, sign sheeting system manufacturer, Type, and the fabricator's initials. For Type VI non-reflective vinyl work zone signs, label the back of all finished panels at the bottom edge with "Daytime Use Only". Make the labels unobtrusive, but legible enough to be easily read by an observer on the ground when the sign is in its final position. Apply the label in a manner that is at least as durable as the sign face.

Properly package signs to protect them during storage, shipment and handling to prevent damage to the sign face and panel.

SECTION 995
TRAFFIC CONTROL SIGNAL AND DEVICE MATERIALS

995-1 Description.

995-1.1 General: This Section governs the requirements for all permanent traffic control signals and devices. All equipment shall be permanently marked with manufacturer name or trademark, part number, and date of manufacture or serial number.

995-1.2 Product Acceptance: All specified products shall be items listed on the Department's Approved Product List (APL), unless otherwise noted below. Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation. A separate application must be submitted for each product to be evaluated, showing that the product meets the applicable requirements.

Table 995-1

Documentation	Requirements
Assembly and Installation Instructions	Include any surface preparations, assembly/installation instructions, operation manual, troubleshooting guides, and repair procedures.
Independent Laboratory Test Results	Product meets requirements of this Section.
Product Label Photo	Labeling shows the manufacturer's name, trademark, and product model number/name. Label shows the date of manufacture and/or the manufacturer's batch number. Additional label requirements, as listed within this Section.
Product Photo	Displays the significant features of the product as required in this section.
Compliance Matrix	Include completed compliance matrix at https://www.fdot.gov/traffic/traf-sys/product-specifications.shtm
Manufacturer's Product Specifications	Include product specifications showing electrical requirements, voltages, etc.
Product Drawings or Cut Sheet	Show mounting points, mechanical details, block diagrams, schematics, etc.
Parts List	List major parts and field serviceable components.

995-1.3 Abbreviations: The following abbreviations are used in this Section:

Acrylonitrile Butadiene Styrene (ABS)
Alternating Current (AC)
Direct Current (DC)
Electronic Industries Alliance (EIA)
Global Positioning System (GPS)
Hypertext Transfer Protocol (HTTP)
Institute of Transportation Engineers (ITE)
Internet Protocol (IP)

Local Area Network (LAN)
Network Time Protocol (NTP)
Telecommunications Industry Association (TIA)
Uniform Code Flash (UCF)
Uniform Resource Locator (URL)
Ultraviolet (UV)

995-2 Vehicle Detection Systems.

995-2.1 General: All parts shall be constructed of corrosion-resistant materials, such as UV stabilized or UV resistant plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements shall be Type 304 or 316 passivated stainless steel.

If the assembly includes a cabinet, meet the requirements of Section 676.

Detectors shall meet the environmental requirements of NEMA TS 2-2021.

995-2.2 Inductive Loop Detector Units: Rack mount inductive loop detector units shall meet the requirements of NEMA NEMA TS 2-2021 and CALTRANS TEES 2020. Shelf mount detector units shall meet the requirements of NEMA TS 1-1989.

995-2.3 Video Vehicle Detection System (VVDS):

995-2.3.1 Configuration and Management: The VVDS shall be provided with software that allows local and remote configuration and monitoring. The system shall be capable of displaying detection zones and detection activations overlaid on live video inputs. The VVDS shall meet the following criteria:

1. Allows a user to edit previously defined configuration parameters, including size, placement, and sensitivity of detection zones.

2. Retains its programming in nonvolatile memory. The detection system configuration data shall be capable of being saved to a computer and restored from a saved file. All communication addresses shall be user programmable.

3. Offers an open Application Programming Interface (API) and software development kit available to the Department at no cost for integration with third party software and systems.

995-2.3.2 Detection Camera: Camera shall be recommended by the video detection system manufacturer. Cameras that are integrated and included in a VVDS shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216.

995-2.3.3 Machine Vision Processor: The VVDS shall include a machine vision processor that allows video analysis, presence detection, data collection, and interfaces for inputs and outputs as well as storage and reporting of collected vehicle detection data.

995-2.3.4 Communications: The VVDS shall include a minimum of one serial or Ethernet communications interface and shall meet the following criteria.

1. Serial interface and connectors shall conform to TIA-232 standards. Ensure that the serial ports support data rates up to 115200 bps; error detection utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

2. Wired Ethernet interfaces shall provide a 10/100 Base TX connection. Verify that all unshielded twisted pair/shielded twisted pair network cables and connectors comply with TIA-568.

3. Wireless communications shall be secure and wireless devices shall be Federal Communications Commission (FCC) certified. The FCC identification number shall be

displayed on an external label and all detection system devices shall operate within their FCC frequency allocation.

4. Cellular communications devices shall be compatible with the cellular carrier used by the agency responsible for system operation and maintenance.

5. The system shall be configured and monitored via one or more communications interface.

995-2.3.5 Video Inputs and Outputs: Analog video inputs and outputs shall utilize BNC connectors.

995-2.3.6 Solid State Detection Outputs: Outputs shall meet the requirements of NEMA TS 2-2021, 6.5.2.26.

995-2.3.7 Electrical Requirements: The system shall operate using a nominal input voltage of 120 V of alternating current (V_{AC}) and with an input voltage ranging from 89 to 135 V_{AC}. If a system device requires operating voltages other than 120 V_{AC}, a voltage converter shall be supplied.

995-2.4 Microwave Vehicle Detection System (MVDS): Sidefire MVDS sensors shall have a minimum 200-foot range and the capability to detect a minimum of 8 lanes of traffic.

995-2.4.1 Configuration and Management: The MVDS shall be provided with software that allows local and remote configuration and monitoring. The system software shall be capable of displaying detection zones and detection activations in a graphical format. The MVDS shall meet the following criteria:

1. Allows a user to edit previously defined configuration parameters, including size, placement, and sensitivity of detection zones.

2. Retains its programming in nonvolatile memory. Ensure that the detection system configuration data can be saved to a computer and restored from a saved file. Ensure that all communication addresses are user programmable.

3. Detection system software offers an open API and software development kit available to the Department at no cost for integration with third party software and systems.

995-2.4.2 Communications: Major components of the detection system (such as the sensor and any separate hardware used for contact closures) shall include a minimum of one serial or Ethernet communications interface and shall meet the following criteria:

1. The serial interface and connector conforms to TIA-232 standards and the serial ports support data rates up to 115200 bps; error detection utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

2. Wired Ethernet interfaces provide a 10/100 Base TX connection. Verify that all unshielded twisted pair/shielded twisted pair network cables and connectors comply with TIA-568.

3. Wireless communications are secure and that wireless devices are FCC certified. The FCC identification number is displayed on an external label and all detection system devices operate within their FCC frequency allocation.

4. Cellular communications devices are compatible with the cellular carrier used by the agency responsible for system operation and maintenance.

5. The system can be configured and monitored via one or more communications interface.

6. Cameras that are integrated and included in a MVDS shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications

and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216.

995-2.4.3 Solid State Detection Outputs: Outputs shall meet the requirements of NEMA TS2-2021, 6.5.2.26.

995-2.4.4 Electrical Requirements: The microwave detector shall operate with a nominal input voltage of 12 V_{DC} and with an input voltage ranging from 89 to 135 V_{AC}. If any system device requires operating voltages other than 120 V_{AC}, a voltage converter shall be supplied.

The detector shall be FCC certified and has been granted authorization to operate within a frequency range established and approved by the FCC. The FCC identification number shall be displayed on an external label.

995-2.5 Wireless Magnetometer Detection System (WMDS):

995-2.5.1 Configuration and Management: The detection system shall be provided with software that allows local and remote configuration and monitoring and shall meet the following criteria.

1. Allows a user to edit previously defined configuration parameters.
2. Retains its programming in nonvolatile memory and the detection system configuration data can be saved to a computer and restored from a saved file. All communication addresses shall be user programmable.
3. The detection system software offers an open API and software development kit available to the Department at no cost for integration with third party software and systems.

995-2.5.2 Communications: Components of the detection system (such as sensors, access points, and contact closure cards) shall include a minimum of one serial or Ethernet communications interface and shall meet the following criteria.

1. The serial interface and connector conforms to TIA-232 standards and the serial ports support data rates up to 115200 bps; error detection utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).
2. Wired Ethernet interfaces provide a 10/100 Base TX connection and all unshielded twisted pair/shielded twisted pair network cables and connectors comply with TIA-568.
3. Wireless communications are secure and that wireless devices are FCC certified. The FCC identification number is displayed on an external label and all detection system devices operate within their FCC frequency allocation.
4. Cellular communications devices are compatible with the cellular carrier used by the agency responsible for system operation and maintenance.
5. The system can be configured and monitored via one or more communications interface.

995-2.5.3 Solid State Detection Outputs: Outputs shall meet the requirements of NEMA TS2-2021, 6.5.2.26.

995-2.5.4 Electrical Requirements: The WDMS shall operate with an input voltage ranging from 89 to 135 V_{AC}. If any system device requires operating voltages other than 120 V_{AC}, a voltage converter shall be supplied.

995-2.6 Automatic Vehicle Identification (AVI):

995-2.6.1 Configuration and Management: The detection system shall be provided with software that allows local and remote configuration and monitoring.

995-2.6.2 Communications: Components of the detection system (such as sensors, controllers, and processing hardware) shall include a minimum of one serial or Ethernet communications interface and shall meet the following criteria.

1. The serial interface and connector conforms to TIA-232 standards and the serial ports support data rates up to 115200 bps; error detection utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

2. Wired Ethernet interfaces provide a 10/100 Base TX connection and all unshielded twisted pair/shielded twisted pair network cables and connectors comply with TIA-568.

3. Wireless communications are secure and that wireless devices are FCC certified. The FCC identification number is displayed on an external label and all detection system devices operate within their FCC frequency allocation.

4. Cellular communications devices are compatible with the cellular carrier used by the agency responsible for system operation and maintenance.

5. The system can be configured and monitored via one or more communications interface.

995-2.6.3 Probe Data Detector Requirements:

1. Transponder Readers shall be compatible with multiple tag protocols, including Allegro and the protocol defined in ISO18000-6B.

2. Bluetooth Readers shall be capable of operating using either solar power or AC power.

3. License Plate Readers shall not require the use of visible strobes or other visible supplemental lighting.

995-2.6.4 Electrical Requirements: The AVI shall operate with an input voltage ranging from 89 to 135 V_{AC}. If any system device requires operating voltages other than 120 V_{AC}, a voltage converter shall be supplied. For solar powered devices, the detection system must operate for 5 days without solar assistance.

995-2.7 Wrong Way Vehicle Detection Systems (WWVDS):

995-2.7.1 Configuration and Management: The WWVDS shall be provided with software that allows local and remote configuration and monitoring. That the system shall have the capability to display detection zones and detection activations. The WWVDS shall meet the following criteria:

1. WWVDS controllers shall support either an on-board real-time clock/calendar with on-board battery backup, or the controller's internal time clock can be configured to synchronize to a time server using the network time protocol (NTP) in order to maintain the current local date/time information. For NTP, the synchronization frequency must be user configurable and permit polling intervals from once per minute to once per week in one-minute increments. For NTP, the controller must allow the user to define the NTP server by IP address.

2. Allows a user to edit previously defined configuration parameters, including size, placement, and sensitivity of detection zones.

3. Retains its programming in nonvolatile memory. The detection system configuration data shall be capable of being saved to a computer and restored from a saved file. All communication addresses shall be user programmable.

4. Offers an open Application Programming Interface (API) or software development kit available to the Department at no cost for integration with third party software and systems.

995-2.7.2 Communications: Major components of the WWVDS (such as the sensor and any separate hardware used for contact closures) shall include a minimum of one serial or Ethernet communications interface and shall meet the following criteria:

1. The serial interface and connector conforms to TIA-232 standards and the serial ports support data rates up to 115200 bps; error detection utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

2. Wired Ethernet interface provides, at a minimum, a 10/100 Base TX connection. Verify that all unshielded twisted pair/shielded twisted pair network cables and connectors comply with TIA-568.

3. Wireless communications are secure and that wireless devices are FCC certified. The FCC identification number is displayed on an external label and all WWVDS devices operate within their FCC frequency allocation.

4. Cellular communications devices are compatible with the cellular carrier used by the agency responsible for system operation and maintenance.

5. The system can be configured and monitored via one or more communications interface.

6. The WWVDS is compatible with the Department's SunGuide® software. The SunGuide software requirements are listed in supplemental requirement SR-995-2.7.2-01, Supplemental Wrong Way Vehicle Detection System SunGuide HTTP Protocol, as published on the Department's State Traffic Engineering and Operations Office website at the following https://www.fdot.gov/traffic/Traf-Sys/Product-Specifications.shtm.

7. For WWVDS installed on ramps, the device shall:

a. Send an alert to the SunGuide® software when the wrong-way vehicle is detected.

b. Send a sequence of images for up to ten seconds to the SunGuide software that covers a configurable time before and after the wrong-way vehicle detection.

c. Activate all highlighted signs associated with the WWVDS.

8. For WWVDS installed on mainline lanes, the device shall send an alert to the SunGuide® software when the wrong-way vehicle is detected.

9. Cameras that are integrated and included in a WWVDS shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216.

995-2.7.3 Electrical Specifications: Equipment shall operate on solar power or with an input voltage ranging from 89 to 135 V_{AC}. If the device requires operating voltages of less than 120 V_{AC}, supply the appropriate voltage converter. Solar powered systems shall be designed to operate for minimum of 5 activations per day and provide 10 days of operation without sunlight.

995-2.8 Light Detection and Ranging (LiDAR) Vehicle Detection System:

995-2.8.1 Configuration and Management: LiDAR systems shall be provided with software that allows local and remote configuration and monitoring. The system shall be

capable of displaying detection zones and detection activations on superimposed on live images of the point cloud data produced by the system. The LiDAR system shall meet the following criteria:

1. Allows a user to edit previously defined configuration parameters, including size and placement of detection zones.

2. Retains its programming in nonvolatile memory. The detection system configuration data shall be capable of being saved to a computer and restored from a saved file. All communication addresses shall be user programmable.

3. Offers an open Application Programming Interface (API) and software development kit available to the Department at no cost for integration with third party software and systems.

995-2.8.2 LiDAR sensors: System sensors shall be recommended by the system manufacturer as part of the engineered LiDAR system solution. Detection range must extend up to at least 200 feet from the sensor. Multiple sensors shall be used to reduce occlusion and generate an accurate point cloud representation of the installation environment and detected objects.

995-2.8.3 Perception Software and Processor: The LiDAR system shall include a processor that combines data from multiple LiDAR sensors into a single point cloud for object detection, classification, presence detection, and data collection. The processor shall be a rugged industrial PC with CPU, memory, storage, a commercially available host operating system, and all software required for system operation. The processor shall include physical interfaces for connection of sensors, system inputs, and outputs.

995-2.8.4 Communications: All major system components shall include an Ethernet communications interface that provides a 10/100 Base TX connection. All unshielded twisted pair/shielded twisted pair network cables and connectors shall comply with TIA-568.

Wireless communications shall be secure and wireless devices shall be Federal Communications Commission (FCC) certified. The FCC identification number shall be displayed on an external label and all detection system devices shall operate within their FCC frequency allocation.

Cellular communications devices shall be compatible with the cellular carrier used by the agency responsible for system operation and maintenance.

995-2.8.5 Solid State Detection Outputs: Outputs shall meet the requirements of NEMA TS 2-2021, 6.5.2.26.

995-2.8.6 Electrical Requirements: The system shall operate using a nominal input voltage of 120 V of alternating current (V_{AC}) and with an input voltage ranging from 89 to 135 V_{AC}. If a system device requires operating voltages other than 120 V_{AC}, a voltage converter shall be supplied.

995-2.9 Vehicle Presence Detection System Performance Requirements: Presence detectors shall provide a minimum detection accuracy of 98% and shall meet the requirements for modes of operation in NEMA TS2-2021, 6.5.2.17.

995-2.9.1 Vehicle Presence Detection Accuracy: To verify conformance with the accuracy requirements in this Section and as a precondition for listing on the APL, sample data collected from the vehicle detection system will be compared against ground truth data collected during the same time by human observation or by another method approved by the FDOT Traffic Engineering Research Laboratory (TERL). Ensure sample data is collected over several time periods under a variety of traffic conditions. Weight each data sample to represent

the predominant conditions over the course of a 24-hour period. Samples will consist of 15- and 30-minute data sets collected at various times of the day. Representative data periods and their assigned weights are provided in Table 995-2.

Table 995-2 Data Collection Periods			
Period	Intended To Represent	Duration	Weight
Early morning (predawn) [EM]	12:30 a.m. – 6:30 a.m.	15 minutes	24
Dawn [DA]	6:30 a.m. – 7:00 a.m.	30 minutes	2
AM Peak [AMP]	7:00 a.m. – 8:00 a.m.	15 minutes	4
Late AM Off-Peak [LAOP]	8:00 a.m. – 12:00 p.m.	15 minutes	16
Noon [NO]	12:00 p.m. – 1:00 p.m.	15 minutes	4
Afternoon Off-Peak [AOP]	1:00 p.m. – 5:00 p.m.	15 minutes	16
PM Peak [PMP]	5:00 p.m. – 6:00 p.m.	15 minutes	4
Dusk [DU]	6:00 p.m. - 6:30 p.m.	30 minutes	2
Night [NI]	6:30 p.m. - 12:30 a.m.	15 minutes	24
Total Sum of Weights			96

For example, the sample gathered for the Late AM Off-Peak period is intended to represent typical traffic conditions between 8:00 a.m. and 12:00 p.m. Since the sample period's duration is 15 minutes and the actual period of time represented is 4 hours, the multiplication factor or weight assigned is 16, the number of 15-minute intervals in a 4 hour period.

995-2.9.2 Calculation of Vehicle Presence Detection Accuracy: Determine individual lane presence detection accuracy per period by subtracting from 100 percent the absolute difference of the total time monitored and the cumulative error time, divided by total time, expressed as a percentage.

Within the equation in 995-2.9.2.1, "EM" represents the early morning period. The variable "i" represents a detector or detection zone and could vary from 1,…, N, where "N" is the total number of detectors observed. Substitute other detector numbers and periods as necessary to determine accuracy for all detectors during each period (i.e., dawn, AM peak, late AM off peak, etc.).

Variables used in the following equations are identified as follows:

PA = Presence detection accuracy

TT = Total time

CET = Cumulative Error Time (duration of all false and missed calls)

N=Total number of detectors observed

995-2.9.2.1 Early Morning Vehicle Presence Detection Accuracy for a Single Detector Expressed as a Percentage:

$$PA_{EM,\det_i} = 100 - \frac{\left|TT_{EM,\det_i} - CET_{EM,\det_i}\right|}{TT_{EM,\det_i}} x100$$

where:

$PA_{EM,\det_i}$ = Presence detection accuracy of detector *i* during the early morning period.

$TT_{EM,\det_i}$ = Total time that detector *i* was monitored (for instance, the 15-minute minimum duration specified in Table 995-2 for the early morning period).

$CET_{EM,\det_i}$ = Cumulative time that detector *i* was in an error state (indicating a detection with no vehicle present or not indicating a detection when vehicle present) during the monitoring period using human observation or another method approved by the Engineer.

The period accuracy will be the arithmetic mean of all individual detector accuracies.

In the equation in 995-2.9.2.2, "EM" represents the early morning period and "*N*" is the total number of detectors tested. Substitute other periods as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

995-2.9.2.2 Early Morning Vehicle Presence Detection Accuracy for All Detectors Expressed as a Percentage:

$$PA_{EM} = \left(\frac{\sum_{i=1}^{N} PA_{EM,\det_i}}{N} \right)$$

Where:

PA_{EM} = Average accuracy of all detectors during the early morning.

$PA_{EM,\det_i}$ = Accuracy of detector *i* during early morning.

Calculate the roadway segment accuracy over all periods using the equation in 995-2.9.2.3.

995-2.9.2.3 Total Vehicle Presence Detection Accuracy for All Detectors Expressed as a Percentage:

$$PA_{Total} = \frac{[PA_{EM}x24 + PA_{DA}x2 + PA_{AMP}x4 + PA_{LAOP}x16 + PA_{NO}x4 + PA_{AOP}x16 + PA_{PMP}x4 + PA_{DU}x2 + PA_{NI}x24]}{96}$$

Where:

PA_{Total} =Accuracy for all detectors for all periods

PA_{EM} = Accuracy of all detectors during early morning traffic conditions

PA_{DA} = Accuracy of all detectors during dawn traffic conditions

PA_{AMP} = Accuracy of all detectors during AM peak traffic conditions

PA_{LAOP} = Accuracy of all detectors during late AM off-peak traffic conditions

PA_{NO} = Accuracy of all detectors during noon traffic conditions

PA_{AOP} = Accuracy of all detectors during afternoon off-peak traffic conditions

PA_{PMP} = Accuracy of all detectors during PM peak traffic conditions

PA_{DU} = Accuracy of all detectors during dusk traffic conditions

PA_{NI} = Accuracy of all detectors during night traffic conditions

995-2.10 Traffic Data Detection System Acceptance Requirements:

995-2.10.1 Data Accuracy: The vehicle detection system shall be capable of meeting the minimum total roadway segment accuracy levels of 95% for volume, 90% for occupancy, and 90% for speed for all lanes, up to the maximum number of lanes that the device can monitor as specified by the manufacturer.

To verify conformance with the accuracy requirements in this Section and as a precondition for listing on the APL, sample data collected from the vehicle detection system will be compared against ground truth data collected during the same time by human observation or by another method approved by the TERL. Sample data shall be collected over several time periods under a variety of traffic conditions. Weight each data sample to represent the predominant conditions over the course of a 24-hour period. Samples shall consist of 15- and 30-minute data sets collected at various times of the day. Representative data periods and their assigned weights are provided in Table 995-2.

995-2.10.2 Calculation of Volume Accuracy: Determine individual lane volume accuracy per period by subtracting from 100 percent the absolute difference of the total volume measured by the detector and the ground truth volume measurement, divided by the ground truth volume measurement, expressed as a percentage.

In the equation in 995-2.10.2.1, “EM” represents the early morning period. The subscript “*i”* represents a lane at the detection zone on the roadway segment and could vary from 1,…, N, where “N” is the maximum number of lanes being detected. Substitute other lane numbers and periods as necessary to determine the accuracy for each lane during each period (i.e., dawn, AM peak, late AM off-peak, etc.).

Variables and subscripts used in the equations below are identified as follows:

VT = Total volume
VD = Vehicle detection data (in this case, count data)
GT = Ground truth measurement
VA = Volume accuracy

995-2.10.2.1 Early Morning Volume Accuracy for a Lane Expressed as a Percentage:

$$VA_{EM,\ln_i} = 100 - \frac{\left|VT_{EM,VD,\ln_i} - VT_{EM,GT,\ln_i}\right|}{VT_{EM,GT,\ln_i}} x100$$

Where:

VA_{EM,ln_i} = Volume accuracy for early morning traffic conditions in the i th lane.

VT_{EM,VD,ln_i} = Total volume for the 15-minute early morning period using the vehicle detector in the i th lane.

VT_{EM,GT,ln_i} = Total volume for the 15-minute early morning period in the i th lane using human observation or another method approved by the Engineer.

The period volume accuracy will be the arithmetic mean of the lane volume accuracy over all lanes.

In the equation in 995-2.10.2.2, "EM" represents the early morning period and "*N*" is the total number of lanes of detection on the roadway segment under test. Substitute other periods as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

995-2.10.2.2 Early Morning Volume Accuracy Expressed as a Percentage:

$$VA_{EM} = \left(\frac{\sum_{i=1}^{N} VA_{EM,\ln_i}}{N} \right)$$

Where:

VA_{EM} = Average volume accuracy for early morning traffic conditions for all lanes.

VA_{EM,ln_i} = Volume accuracy for early morning traffic conditions in the i th lane.

Calculate the total volume accuracy over all periods using the equation in 995-2.10.2.3.

995-2.10.2.3 Total Volume Accuracy Expressed as a Percentage:

$$VA_{Total} = \frac{[VA_{EM}x24 + VA_{DA}x2 + VA_{AMP}x4 + VA_{LAOP}x16 + VA_{NO}x4 + VA_{AOP}x16 + VA_{PMP}x4 + VA_{DU}x2 + VA_{NI}x24]}{96}$$

Where:

VA_{Total} = Volume accuracy for all lanes for all periods
VA_{EM} = Volume accuracy for early morning traffic conditions
VA_{DA} = Volume accuracy for dawn traffic conditions
VA_{AMP} = Volume accuracy for AM peak traffic conditions
VA_{LAOP} = Volume accuracy for late AM off-peak traffic conditions
VA_{NO} = Volume accuracy for noon traffic conditions
VA_{AOP} = Volume accuracy for afternoon off-peak traffic conditions
VA_{PMP} = Volume accuracy for PM peak traffic conditions
VA_{DU} = Volume accuracy for dusk traffic conditions
VA_{NI} = Volume accuracy for night traffic conditions

995-2.10.3 Calculation of Speed Accuracy: For computing the accuracy of the detector speed measurement, the average speed readings obtained from the detection system are compared to ground truth values.

The equation in 995-2.10.3.1 represents the ground truth average speed computation procedure for a particular lane during a specific time period. The equation in 995-2.10.3.2 represents the average speed computation procedure for a particular lane during a specific time period using data gathered from the detection system.

In the equations in 995-2.10.3.1 and 995-2.10.3.2, the time period described is the early morning period, represented by "EM", and the subscript "k" represents a vehicle traveling on the roadway and could vary from 1,…, K, where "K" is the total number of vehicles in lane i during the time period under consideration. The subscript "i" represents a lane in a roadway and could vary from 1,…, N, where "N" is the total number of lanes of detection on the roadway segment. Substitute other lanes and periods as necessary and compute the accuracy for each lane for all time periods.

Variables and subscripts used in the equations below are identified as follows:

SA = Speed accuracy
S = Speed of an individual vehicle
K = Total number of vehicles in lane during time period
veh = Vehicle

995-2.10.3.1 Early Morning Average Ground Truth Speed:

$$S_{Avg,EM,GT,\ln_i} = \frac{1}{K}\sum_{k=1}^{K} S_{EM,GT,\ln_i,veh_k}$$

Where:

SA_{Avg,EM,GT,ln_i} represents the average ground truth vehicle speed for the i th lane during the early morning period.

S_{EM,GT,ln_i,veh_k} represents the ground truth speed for the k^{th} vehicle in the i^{th} lane during the early morning period using human observation or another method approved by the Engineer.

995-2.10.3.2 Early Morning Average Vehicle Detector Speed:

$$S_{Avg,EM,VD,\ln_i} = \frac{1}{K}\sum_{k=1}^{K} S_{EM,VD,\ln_i,veh_k}$$

Where:

S_{Avg,EM,VD,ln_i} represents the average speed recorded by the vehicle detector for the ith lane during the early morning period.

S_{EM,VD,ln_i,veh_k} represents the speed for the k th vehicle in the i th lane during the early morning period using the vehicle detector.

Determine lane speed accuracy per period by subtracting from 100 percent the absolute difference of the average lane speed measured by the detector and the average lane ground truth speed, divided by the average lane ground truth speed, expressed as a percent.

In the equation in 995-2.10.3.3, "EM" represents the early morning period. The subscript "*i*" represents a lane of detection on a roadway and could vary from 1,…,N, where "N" is the total number of lanes of detection on the roadway segment. Substitute other lanes as necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

995-2.10.3.3 Early Morning Lane Speed Accuracy Expressed as a Percentage:

$$SA_{Avg,EM,\ln_i} = 100 - \frac{\left|S_{Avg,EM,VD,\ln_i} - S_{Avg,EM,GT,\ln_i}\right|}{S_{Avg,EM,GT,\ln_i}} \times 100$$

Where:

SA_{Avg,EM,ln_i} represents the average speed accuracy during early morning traffic conditions for all vehicles that traveled in lane i of the roadway segment.

The period speed accuracy will be the arithmetic mean of the lane speed accuracy, computed using the equation in 995-2.10.3.3, over all lanes.

In the equation in 995-2.10.3.4, "EM" represents the early morning period. The subscript "i" represents a lane of detection on a roadway and could vary from 1,…, N, where "N" is the maximum number of lanes on the roadway segment. Substitute data as

necessary to determine the accuracy for each period (i.e., dawn, AM peak, late AM off-peak, etc.).

995-2.10.3.4 Early Morning Speed Accuracy Expressed as a Percentage:

$$SA_{EM} = \left(\frac{\sum_{i=1}^{N} SA_{Avg,EM,\ln_i}}{N} \right)$$

Where:

SA_{EM} represents the average speed accuracy during early morning traffic conditions for all lanes of detection on the roadway segment.

Calculate detector speed accuracy for the roadway segment over all periods using the equation in 995-2.10.3.5.

995-2.10.3.5 Total Roadway Segment Accuracy Expressed as a Percentage:

$$SA_{Total} = \frac{[SA_{EM}x24 + SA_{DA}x2 + SA_{AMP}x4 + SA_{LAOP}x16 + SA_{NO}x4 + SA_{AOP}x16 + SA_{PMP}x4 + SA_{DU}x2 + SA_{NI}x24]}{96}$$

Where:

SA_{Total} = Speed accuracy for all lanes for all periods
SA_{EM} = Speed accuracy for early morning traffic conditions
SA_{DA} = Speed accuracy for dawn traffic conditions
SA_{AMP} = Speed accuracy for AM peak traffic conditions
SA_{LAOP} = Speed accuracy for late AM off-peak traffic conditions
SA_{NO} = Speed accuracy for noon traffic conditions
SA_{AOP} = Speed accuracy for afternoon off-peak traffic conditions
SA_{PMP} = Speed accuracy for PM peak traffic conditions
SA_{DU} = Speed accuracy for dusk traffic conditions
SA_{NI} = Speed accuracy for night traffic conditions

995-2.11 Probe Data Detection System Performance Requirements: Probe data detectors shall establish a unique and consistent identifier for each vehicle detected and the time and location that the vehicle was detected and shall provide the following:

1. A minimum match rate of 5% for probe data detection systems that match upstream and downstream detection of the same vehicle
2. A minimum total roadway segment speed and travel time accuracy level of 90%. Verify system performance over several time periods under a variety of traffic conditions as described in 995-2.9.1.

995-2.11.1 Calculation of Match Rate: Match rate is the percentage of the total vehicle population of a road segment that is detected and matched at consecutive probe data detection sites.

995-2.11.1.1 Early Morning Match Rate Expressed as a Percentage:

$$MR_{EM} = 100 - \frac{\left|M_{EM,VD} - V_{EM,GT}\right|}{V_{EM,GT}} \times 100$$

Where:

MR_{EM} = Match Rate for early morning.

$M_{EM,VD}$ = Number of matched detections between two probe vehicle detection sites (typically a pair of sites at each end of a roadway segment) during early morning.

$V_{EM,GT}$ = Total volume of vehicles that pass the detection area for the 15-minute early morning period using human observation or another method approved by the Engineer.

995-2.12 Wrong Way Vehicle Detection System Accuracy: To verify conformance with the accuracy requirements in this Section and as a precondition for listing on the APL, sample data collected from the WWVDS will be compared against ground truth data collected during the same time by human observation or by another method approved by the FDOT Traffic Engineering Research Laboratory (TERL).

WWVDS accuracy testing shall be performed under controlled conditions at the TERL facility. The wrong way vehicle detection system must be capable of meeting a true positive detection accuracy of 100% using a sample size of 100 wrong way vehicle runs. Sample data shall be collected over several time periods under a variety of conditions. System operation will be monitored for 72 hours. The wrong way vehicle detection system shall not exceed one false positive per 24-hours during the monitoring period.

995-2.12.1 Calculation of WWVDS) System Accuracy: Determine true positive detection accuracy by dividing the number of valid wrong way vehicle detections by the number of vehicles.

995-2.12.1.1 Wrong Way Vehicle Detection System Accuracy expressed as a Percentage:

$$TPDA = \frac{WWVD}{N}\ x\ 100$$

Where:

TPDA = True Positive Detection Accuracy

WWVD = Number of Wrong Way Detections reported by system

N = Total number of wrong way vehicle runs

995-3 Loop Sealant.

Loop sealant shall be furnished in a premeasured two-part formulation and meet the following requirements:

Table 995-3 Loop Sealant Properties		
Property	Test Method	Performance Criteria
Self-leveling		
Viscosity	ASTM D562 @77°F	Sealant shall not run out of unlevel slots
Adhering to concrete and asphalt	Install in 3/8 inch by 3-inch saw cut, cure for 2 weeks at 77°F	Visual inspection: sealant shall securely adhere to concrete and asphalt No visible signs of shrinkage after curing when tested for shrinkage using a dimensional measurement
Curing	ASTM C679 at 77°F	Tack-Free at 2 hours from time of application
Resistance to Fluids	ASTM D570	Sealant shall resist weather, oils, gasoline, antifreeze, and brake fluid when tested for absorption for water, No. 3 oil, gasoline, antifreeze, and brake fluid for 24 hours
Penetration	ASTM D2240 Shore A	Sealant shall resist penetration of foreign materials when tested for durometer hardness for 24 hours
Expansion Cracking	ASTM D412	Sealant shall resist cracking caused by expansion and contraction due to temperature changes when tested for tensile strength and elongation
Cracking	ASTM C1246	Sealant shall not become brittle with age or temperature extremes when tested for weight loss, cracking, and chalking
Shelf Life	Manufacturer's Recommendations	Sealant shall have a minimum shelf life of 12 months when stored in accordance with the manufacturer recommendations

995-4 Vehicular Traffic Signal Assemblies.

995-4.1 General: Vehicular traffic signal assemblies must meet the requirements of Section 603 and the ITE Standard for Vehicle Traffic Control Signal Heads.

Fastening hardware such as bolts, screws, nuts, washers, latches, and studs must be SAE Type 316 or 304 stainless steel.

Horizontal signal assemblies must be constructed so the door hinges, when installed, are located on the bottom of the signal assembly. Vertical mounted five-section cluster assemblies must be constructed so that the door hinges, when installed, are located along the outside edges of the complete assembly and each section opens away from the horizontally adjacent section.

995-4.2 Twelve Inch Signal Head Assemblies: Construct the assembly of materials and alloys specified in the ITE Standard for Vehicle Traffic Control Signal Heads.

Construct signal housings to allow adjustment in multiple directions for proper signal alignment. If a serrated connection is used for positioning and alignment of the signal, the top and bottom opening of each signal head section must include a circular 72-tooth serrated connection (2-inch nominal I.D.) capable of providing positive positioning and alignment in 5-

degree increments. When assembled and tightened, these connections must prevent rotation or misalignment of the signal head as well as misalignment between sections. The serrated area must start at the outside of the 2-inch hole and be at least 1/8 inch wide. The teeth must have a minimum depth of 3/64 inch between peaks and valleys, be free from burrs or other imperfections, and provide positive locking with the grooves of mating sections, framework, and brackets. The serration on the top circular connection of a signal section must have a valley at the 0-degree position and the serration on the bottom circular connection must have a peak at the 0-degree position, both aligned perpendicular to the front of the section. Connections must permit the assembly of a multi-section signal with the front of each section aligned within 1 degree.

Provide at least two latching points with latch pads and manual Type 316 or 304 stainless steel latching devices that are tamper resistant.

If backplates are mechanically attached, each signal section must have four backplate mounting attachment points on the back of the signal, on or no more than three inches from each section corner. Attachment points must be capable of accepting No. 10-16x3/8 inch or No. 10-24x3/8 inch Type 316 or 304 stainless steel screws for attaching backplates.

Tri-stud washers, when utilized to secure signal sections, must have a minimum thickness of 0.090 inch. For five-section cluster assemblies, tri-stud washers used to attach the top signal section to the multi-signal bracket and the multi-signal bracket to the bottom four signal sections must have a minimum thickness of 3/8 inch. When fastened together, washer distortion is not allowed.

Design each signal section to prevent the accumulation of standing water within the assembly. All sections comprising a single multi-section assembly must be securely fastened together to form a rigid and weather-proof unit.

995-4.2.1 Doors: Construct each signal section with at least two hinges for mounting a door. Hinge pins must be captive. Doors must remain captive and secure at all times and be capable of either left or right swing. The door latch must hold the door tightly closed. The door must include slotted pads that allow the door to be opened and closed by engaging or disengaging the latching device. The outside face of the door must include four holes equally spaced around the circumference of the lens opening for the attachment of a visor. The lens opening in the door must have a diameter of 11 to 11-1/2 inches.

995-4.2.2 Visors: The rear of the visor must have four tabs, notches, or holes for securing the visor to the signal housing door. The visor mounting method must permit the visor to be rotated and secured at 90 degrees for horizontal signal head installations. All visors must have a minimum length of 9-1/2 inches, and a minimum downward tilt of 3.5 degrees measured from the center of the lens. Tunnel visors must encircle and shield the lens from 300 degrees, plus or minus 10 degrees. Louvers may only be used in combination with full circle visors. Light must not escape between the visor and the door.

995-4.2.3 Gaskets: Gaskets must be constructed of weather-resistant material and be glued or sealed where they meet to provide one continuous length of gasket capable of providing a weatherproof seal for the signal assembly. Provide seals between the housing and door, between the lens and the door, and between any other mating surfaces where dust and moisture could enter. Gasket material must meet NEMA 250 and be constructed of temperature stabilized material that prevents any residue from collecting on the internal surfaces of the signal head.

995-4.2.4 Terminal Blocks: Provide at least one five-connection terminal block in all three or more section signal head assemblies and at least three five-connection terminal

blocks in all five section signal head assemblies. Terminal block connections in the signal assembly must not require any tools other than a screwdriver.

Mount terminal blocks to the signal housing with Type 316 or 304 passivated stainless steel hardware. Use only non-corrosive wire attachment screws approved by the Department.

995-4.2.5 Color and Finish: The housing, doors, visors and backplates must be powder coated dull black (Federal Standard 595-37038) with a reflectance value not exceeding 25 percent as measured by ASTM E1347. For plastic heads, the black color must be incorporated into the plastic material before molding.

The finish on interior and exterior surfaces of aluminum signal head assemblies, visors, doors, and housing, must be painted in accordance with Military Standard MIL-PRF-24712A or American Architectural Manufacturers Association (AAMA) -2603-02 and must meet the requirements of ASTM D3359, ASTM D3363, and ASTM D522. Surface erosion, flaking, or oxidation must not occur within the normal life expectancy under typical installation conditions.

995-4.2.6 Plastic Signal Housings and Visors: Construct signal housing assembly, door, and visors of UV stabilized plastic with a minimum thickness of 0.1 inch, plus or minus, 0.01 inch, with the following physical properties:

Table 995-4
Plastic Signal Housings and Visors

Test	Minimum Requirement	Method
Specific Gravity	1.17	ASTM D792
Vicat Softening Temp.	305-325°F (152 – 163°C)	ASTM D1525
Brittleness Temp.	Below -200°F (-129°C)	ASTM D746
Flammability	Self-extinguishing	ASTM D635
Tensile Strength	Yield, 8500 psi (58 MPa)	ASTM D638
Elongation at yield	5.5 - 8.5%	ASTM D638
Shear Strength	Yield, 5500 psi (38 MPa)	ASTM D732
Izod impact strength	15ft-lb/in (800 J/m)	ASTM D256
Fatigue strength	950 psi (6.5MPa) at 2.5 mm cycles	ASTM D671
Fatigue strength	950 psi (6.5MPa) at 2.5 mm cycles	ASTM D671

995-4.2.7 Backplates: Backplates may be constructed of either aluminum or plastic. Minimum thickness for aluminum backplates is 0.060 inch and the minimum thickness for plastic backplates is 0.120 inch. Backplate thickness measurement must not include the retroreflective sheeting thickness. The width of the top, bottom, and sides of backplates must measure between five to six inches. Color of backplates must be black in accordance with 995-4.2.5.

If backplates are mechanically attached, provide a minimum of four corner mounting attachment points per signal section (for example, a three-section signal assembly would have 12 mounting points). Attachment points must not interfere with the operation of traffic signal section doors. Backplate outside corners must be rounded and all edges must be de-burred.

If louvers are provided, louver orientation must be vertical on sides and horizontal on top and bottom of the backplate and must be at least 1/2 inch from the inner and

outer edge of the backplate panel. Universal backplates must fit all traffic signals listed on the APL.

Mount the backplate securely to the signal assembly with Type 316 or 304 passivated stainless steel installation hardware. Backplates, if mechanically attached, must be marked in accordance with 995-1, on the long sides of the backplate.

Backplates must include retroreflective borders using Type IV yellow retroreflective sheeting listed on the APL. Place a 2-inch border on the entire outer perimeter of the backplate panel, no closer than 1/2 inch from any louvers.

All materials must be designed for exterior use and be UV stable.

995-4.2.7.1 Flexible Backplates: Flexible backplates must allow the entire length of longer portions of the backplate to flex 90 degrees, or until the backplate width is reduced to 2.5 inches or less, when influenced by high wind conditions, and return to zero degrees after the wind conditions subside. Flexible backplates must maintain visibility of the retroreflective border to approaching traffic, with up to 40 mph winds.

995-4.2.8 Light-Emitting Diode Optical Unit: The LED optical unit must conform to the requirements of ITE's Performance Specification, Vehicle Traffic Control Signal Heads - Light Emitting Diode (LED) Circular Signal Supplement, dated June 27, 2005 or Vehicle Traffic Control Signal Heads - Light Emitting Diode (LED) Vehicle Arrow Traffic Signal Supplement, dated July 1, 2007, with the following exceptions.

1. Retrofit LED signal modules must be compatible with all traffic signal housings listed on the APL. The rear of the LED signal module must be marked in accordance with 995-4.1.

2. The lens must be tinted with an appropriate color (red, amber, or green) to reduce sun phantom affect and enhance on/off contrast. The tinting must be uniform across the face of the lens and be free from streaks, wrinkles, chips, bubbles, or other imperfections. If a polymer lens is used, a surface coating must be incorporated to provide abrasion resistance.

3. Red and green modules must meet the requirements of ITE's Performance Specification, Vehicle Traffic Control Signal Heads - Light Emitting Diode (LED) Circular Signal Supplement, dated June 27, 2005, with the exception that yellow modules must be 1.7 times brighter than the ITE specification. Arrow modules must meet the requirements of ITE's Performance Specification, Vehicle Traffic Control Signal Heads - Light Emitting Diode (LED) Vehicle Arrow Traffic Signal Supplement, dated July 1, 2007.

995-4.2.9 Electrical: Electrical conductors for LED signal modules must be a minimum of 36 inches in length. Each lead from the LED module must be terminated with insulated slide-on terminals. The conductors must be color coded to identify the color of the module as follows:

1. White must identify the neutral lead.

2. Red circular signals must be identified with a red lead, yellow circular signals with a yellow lead, and green circular signals with a green lead.

3. Red arrows must be identified with a red and black tracer lead, yellow arrows with a yellow and black tracer lead, and green arrows with a green and black tracer lead.

995-5 Pedestrian Signal Assemblies.

995-5.1 General: Pedestrian signal assemblies must meet the requirements of Section 603, the MUTCD, and the ITE standard for Pedestrian Traffic Control Signal Indications.

995-5.2 Housing and Visor: The housing must be weatherproof, sectional and may consist of as many sections as optical units. The housing must prevent light from escaping from one unit to another. The top and bottom opening of the housing must include a circular 72-tooth serrated connection (2-inch nominal I.D.) capable of providing positive positioning and alignment in 5 degree increments. When assembled and tightened, these connections must prevent rotation or misalignment. The serrated area must start at the outside of the 2-inch hole and be at least 1/8 inch wide. The teeth must have a minimum depth of 3/64 inch between peaks and valleys, free from burrs or other imperfections, and provide positive locking with the grooves of mating sections, framework, and brackets. The serration on the top circular connection of a signal section must have a valley at the 0-degree position and the serration on the bottom circular connection must have a peak at the 0-degree position, both aligned perpendicular to the front of the section. Housings must include latch pads and manual stainless steel latching devices that are captive, or non-removable. Housings must have at least two latching points.

Reinforce all mounting points and adjacent housing material. The door enclosing the lens must be hinged and held securely to the housing. Provide a gasket meeting the requirements of ASTM D1056, Grade 2B2 between the housing and door and between the lens and door. If the fitting between the housing and door is weather-tight, the gasket may be omitted.

Provide a visor or egg-crate louver that eliminates sun phantom for each signal face. Visor must be three-sided and extend a minimum of 7 inches at the top from the face of the lens. The visor must be constructed of noncorrosive No. 18 gauge sheet metal, not less than 0.05 inch thick, or 0.1 inch thick polycarbonate.

All metal housings and visors must be powder-coat painted black in accordance with Military Standard MIL-PRF-24712A or AAMA-2603-02 with a reflectance value not exceeding 25 percent as measured by ASTM E97. For polycarbonate heads, the black color must be incorporated into the material before the molding process.

The housing must be constructed of a non-corrosive material. Cast metal parts must have a minimum tensile strength of 1 ksi (117 MPa) and sheet metal parts a minimum tensile strength of 27 ksi (186 MPa).

995-5.2.1 Die Castings: Meet the requirements in ASTM B85 for the physical characteristics and chemical content for alloys S12A, S12B, SC84A, SC84B, SG100A and SG100B.

995-5.2.2 Sand Castings: Meet the requirements in ASTM B26 for the physical characteristics and chemical content for alloys S5A and CS72A.

995-5.2.3 Permanent Mold Castings: Meet the requirements in ASTM B108 for the physical characteristics and chemical content for alloys S5A and CS72A.

995-5.2.4 Polycarbonate: Polycarbonate housing assemblies, doors and visors must be molded from ultraviolet stabilized polycarbonate plastic with a minimum thickness of 0.1 inch, plus or minus 0.01 inch, and provide the following physical properties:

Table 995-5 Polycarbonate Housing Assemblies, Doors, and Visors		
Test	Minimum Requirement	Method
Specific Gravity	1.17	ASTM D792
Vicat Softening Temp.	305-325°F (152 – 163°C)	ASTM D1525
Brittleness Temp.	Below -200°F (-129°C)	ASTM D746
Flammability	Self-extinguishing	ASTM D635
Tensile Strength	Yield, 8500 psi (58 MPa)	ASTM D638
Elongation at yield	5.5 - 8.5%	ASTM D638
Shear Strength	Yield, 5500 psi (38 MPa)	ASTM D732
Izod impact strength	15ft-lb/in (800 J/m)	ASTM D256
Fatigue strength	950 psi (6.5MPa) at 2.5 mm cycles	ASTM D671

995-5.3 Light Emitting Diode (LED) Pedestrian Signal Optical Unit (State Standard): Provide a countdown pedestrian signal module meeting the requirements of the latest ITE LED Pedestrian Signal Specifications.

995-5.4 Electrical: Wiring and terminals must meet the size, insulation, length, and color-coding of the current ITE Pedestrian Traffic Control Signal Indicators LED specification. Wires must not have bare wiring exposed where wires are secured.

The pedestrian signal must include a terminal block containing a minimum of three circuits, each with two noncorrosive screw-type terminals. Each terminal must accommodate three No. 18 AWG conductors and be labeled for ease of identification. The terminal block must not be obstructed and be visible when the housing is open.

995-5.5 Hardware: All brackets used to mount pedestrian signals must be an aluminum alloy cast fitting, pipe, or equivalent material approved by the Department. Aluminum and aluminum alloy bars, rods, wires, profiles, and tubes must meet ASTM B221. Aluminum-alloy sand casting must meet ASTM B26. All mounting hardware must be painted black with a reflectance value not exceeding 25 percent as measured by ASTM E97.

Ensure that all assembly hardware, including nuts, bolts, external screws and locking washers less than 5/8 inch in diameter, are Type 304 or 316 passivated stainless steel. Stainless Steel bolts, screws and studs must meet ASTM F593. Nuts must meet ASTM F594. All assembly hardware greater than or equal to 5/8 inch in diameter must be galvanized. Bolts, studs, and threaded rod must meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

995-6 Midblock Crosswalk Enhancement Assemblies.

995-6.1 General: Midblock crosswalk enhancement assemblies are classified as the following types: In-Roadway Light Assemblies and Rectangular Rapid Flashing Beacon Assemblies (RRFB).

995-6.2 In-Roadway Light Assemblies: In-roadway light assemblies must meet the physical and operational requirements of the latest edition of the MUTCD, Chapter 4N.

In-roadway light assemblies can include a passive detector in addition to a pedestrian pushbutton. In-roadway light assemblies must be normally dark and initiate operation upon pedestrian actuation via a pedestrian pushbutton or a passive detector. The In-roadway light assembly will cease operation at a predetermined time after the pedestrian actuation. If a passive detector is used, the In-roadway light assembly may cease operation after the pedestrian clears

the crosswalk. The duration of the predetermined period shall be programmable and capable of matching the pedestrian clearance time for pedestrian signals as determined by MUTCD procedures. The timer that controls flashing must automatically reset each time a pedestrian call is received.

In-roadway light assemblies must have a minimum luminance of 101 candelas and a minimum viewing angle of 20 degrees.

995-6.3 Rectangular Rapid Flashing Beacon (RRFB): RRFB must include two rapidly and alternately flashed rectangular yellow indications having LED-array based pulsing light sources. Each rectangular yellow indication must be a minimum of five inches wide by two inches high. RRFB installations shall comply with the use and technical conditions of FHWA MUTCD Interim Approval 21 – Rectangular Rapid-Flashing Beacons at Crosswalks. The two RRFB indications shall be aligned horizontally, with the longer dimension horizontal and with a minimum space between the two indications of approximately 7 inches measured from inside edge of one indication to inside edge of the other indication.

995-6.3.1 Beacon Flashing Requirements: The light intensity of the yellow indications shall meet the minimum specifications of SAE Standard J595 for Class 1 (Directional Flashing Optical Warning Devices for Authorized Emergency, Maintenance, and Service Vehicles) dated January 2005. Ensure RRFB assemblies are capable of automatically dimming to reduce brightness of the LEDs at nighttime.

The flash rate of each individual yellow indication, as applied over the full on-off sequence of a flashing period of the indication, shall not be between 5 and 30 flashes per second. When activated, the two yellow indications in each RRFB shall have a flash rate of 75 flash cycles per minute using the following sequence: left side beacon on for 50 milliseconds (msec), both beacons off for 50 msec, right side beacon on for 50 msec, both beacons off for 50 msec, left side beacon on for 50 msec, both beacons off for 50 msec, right side beacon on for 50 msec, both beacons off for 50 msec, both beacons on for 50 msec, both beacons off for 50 msec, both beacons on for 50 msec, both beacons off for 250 msec. No other flash patterns shall be selectable via hardware or software.

995-6.3.2 RRFB Operation: RRFB can include a passive detector in addition to a pedestrian pushbutton. RRFBs must be normally dark and initiate operation only upon pedestrian actuation via a pedestrian pushbutton, or a passive detector. The RRFB will cease operation at a predetermined time after the pedestrian actuation. If the passive detector is used, the RRFB may cease operation after the pedestrian clears the crosswalk. The duration of the predetermined period shall be programmable and capable of matching the pedestrian clearance time for pedestrian signals as determined by MUTCD procedures. The timer that controls flashing must automatically reset each time a pedestrian call is received.

All RRFBs associated with a single crosswalk (including those with an overhead or advance crossing sign, if used) shall simultaneously commence operation of their alternating rapid flashing indications and shall cease operation simultaneously.

RRFBs must include an instruction sign (FTP-68C-21) mounted adjacent to or integral with each pedestrian pushbutton, in accordance with the Standard Plans, Index No. 654-001.

A confirmation light directed at and visible to pedestrians in the crosswalk must be installed integral to the RRFB to give confirmation that the RRFB is in operation.

995-6.3.3 Midblock Accessible Pedestrian Pushbutton: The assembly must contain a speaker, audio amplifier, and noise monitoring microphone for auto volume control.

The accessible pedestrian pushbutton detector must meet 995-9.3 for the locator tone feature. The pushbutton must not include a vibrotactile indication or percussive indications. The audible message must be programmable.

995-6.4 Cabinets, Housings, and Hardware: Cabinets used as part of the midblock crosswalk enhancement assembly must be currently listed on the APL or meet the requirements of Section 676.

All housings other than approved cabinets must be powder coat painted dull black per SAE AMS-STD-595A with a reflectance value not exceeding 25 percent as measured by ASTM E1347. Cabinets and housings must prevent unauthorized access.

Pole-mount assemblies shall allow installation on 4-1/2 inch outer diameter posts.

Ensure all assembly hardware, including nuts, bolts, external screws, and locking washers less than 5/8 inch in diameter, are Type 304 or 316 passivated stainless steel. Stainless steel bolts, screws, and studs must meet ASTM F593. Stainless steel nuts must meet ASTM F594. All assembly hardware greater than or equal to 5/8 inch in diameter must be galvanized. Carbon steel bolts, studs, and threaded rod must meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

995-6.5 Electrical Specifications: Equipment must operate on solar power or a nominal voltage of 120 V_{AC}. If the device requires operating voltages of less than 120 V_{AC}, supply the appropriate voltage converter. Solar powered systems must be designed to operate for minimum of 100 activations per day and provide 10 days of operation without sunlight. Each activation must be 30 seconds in duration. Solar powered systems must automatically charge batteries and prevent overcharging and over-discharging. Solar powered systems must include a charge indicator.

995-6.6 Environmental Specifications: All electronic assemblies shall operate as specified during and after being subjected to the transients, temperature, voltage, humidity, vibration, and shock tests described in NEMA TS2-20218.3, 2.2.7, 2.2.8, and 2.2.9. Electronics must meet FCC Title 47, Subpart B, Section 15. The optical portion of the housing shall be sealed to provide an IP 67 rating.

995-7 Mast Arm, Span Wire, and Pole Mounting Assemblies.

995-7.1 General: Fastening hardware such as bolts, nuts, washers, set screws, studs, u-bolts, cable and cable swags, must be provided by the mounting assembly manufacturer, must be SAE Type 316 or 304 stainless steel. Hardware (studs, bolts and u-bolts) must be a minimum of 5/16 inch diameter unless otherwise specified in this Section. SAE Grade 8 bolts and nuts are also acceptable. Metallic mounting assemblies must meet ASTM B117 for corrosion resistance.

Connections that provide an entrance to the interior of a traffic device must be weather-resistant.

All assemblies must be constructed to support the weight of any combination of signal indications with all accessories such as back plates and visors.

Connections between signal, disconnect and disconnect hanging hardware must be of the tri-stud design unless otherwise specified in this Section. Tri-stud washers must be a minimum 0.090 inch thick unless otherwise specified in this Section.

Connections must be designed to mate with a standard traffic signal's 2-inch I.D. opening and must be capable of providing positive positioning and alignment of the traffic device. Connection type may be a 72-tooth serrated edge or other connection type as long as all other specifications are met. For 72-tooth serrated edge connections, the teeth must be clean,

sharp, and at least 1/8 inch wide and 3/64 inch deep. All connection types must be weather resistant.

All mounting assemblies must be capable of providing adjustment in multiple directions for proper alignment of the attached traffic device and to prevent rotation around the vertical axis or misalignment after installation.

Use studs that are either cast directly into the aluminum during the casting process or tapped and locked with a locking material. In each case, a pull-out force must be provided. Messenger wire clamps must be extruded aluminum six inches long or cast U-bolt type.

Torque specifications must be included for all fastening hardware with the assembly installation instructions.

995-7.2 Product Identification: Mounting assemblies must be permanently marked in accordance with 995-1. Identification must be cast into, or metal-marked on, the assembly in a legible manner. When the assembly is made up of multiple components, each component must be identified with the manufacturer's name or trademark.

995-7.3 Finish: Unless otherwise specified, mounting assemblies and components must be supplied with a natural finish with mill scale removed in accordance with Military Standard MIL-PRF-24712A or AAMA 2603-02 and must meet the requirements of ASTM 3359 and ASTM D3363. Disconnect (interior and exterior) and disconnect hub must be powder-coat painted dull black (Federal Standard 595A-37038) with a reflectance value not exceeding 25 percent as measured by ASTM E97. All finished surfaces must have a smooth finish free from cracks, blow-holes, shrinks, excessive material, and other flaws.

995-7.4 Mast Arm Mounting Assemblies: Mast arm mounting assemblies must include the following components: mast arm saddle, swivel, attachment cables (with cable clamp mechanism) or bands. Unless the assembly uses a free-swinging mounting method, mast arm mounting assemblies must include the support tube, and top and bottom support arms. Mast arm mounting assemblies must be designed to be attached to a mast arm by cables or bands. All connections must be designed to prevent movement when 250 pounds of downward force is applied to the completed vehicular traffic signal assembly.

995-7.4.1 Saddle: Saddles must be aluminum or stainless steel and must have a minimum yield strength of 16 ksi and a minimum ultimate tensile strength of 23 ksi in accordance with ASTM B26, ASTM B108, ASTM B85 or ASTM A240.

995-7.4.2 Swivel: Swivels must be aluminum or stainless steel and must have a minimum yield strength of 16 ksi and a minimum ultimate tensile strength of 23 ksi in accordance with ASTM B26, ASTM B108, ASTM B85 or ASTM A240. The swivel must provide at least two connection devices to secure the support tube to the swivel and be configured to permit the support tube to provide adjustment in multiple directions in a plane parallel to the mast arm. Any castings used to attach the support tube to the swivel must be manufactured from the same alloy as the swivel.

995-7.4.3 Saddle Attachment Cables and Bands: Mast arm saddle attachment cables must be 3/16-inch minimum diameter, Type 316 or 304 stainless steel aircraft type wire strand cable. The swage at the ends of the cable (used to tighten the cable against the saddle) must be Type 316 or 304 stainless steel with a minimum 3/8-inch diameter thread. The swage must permit use of a wrench to prevent rotation while tightening the nut at the end of the swage. If the attachment cable does not have swaged clamp screws at each end (double-ended), the unclamped end of the cable must be sintered, welded, or otherwise secured without adhesives to prevent unraveling of the cable. Banding must use two Type 304 or 201 series stainless steel

3/4 inch wide bands and Type 316 stainless steel buckles (clamp screws). De-burr the edges of the bands.

995-7.4.4 Cable Clamp Mechanism: Mast arm mount components used to secure the cable to the saddle must be aluminum or stainless steel and must have a minimum yield strength of 23 ksi and a minimum ultimate tensile strength of 30 ksi in accordance with ASTM B26, ASTM B221, ASTM B85 or ASTM A240.

995-7.4.5 Support Tube: Support tubes used in mast arm mounting assemblies must be aluminum or stainless steel and must have a minimum yield strength of 25 ksi and a minimum ultimate tensile strength of 30 ksi in accordance with ASTM B221 or ASTM A240. A gusseted hollow design may be used to provide for the routing of necessary wiring. The tube cross-sectional area's principal moments of inertia must average; at a minimum, that of a 1.5-inch standard aluminum Schedule 40 pipe and the cross-sectional metal area must not be less than that of a 1.5-inch Schedule 40 pipe. The bottom portion of the tube that supports the vertical load of the hanging device must be threaded using National Pipe Thread Taper (NPT), National Pipe Thread Straight (NPS), non-threaded U-bolt secured, or a continuous arm support tube. Threaded support tubes that are fully slotted must have an aluminum insert in the 3/4-inch slot extending a minimum of 1/2-inch beyond the threaded section. To provide easy installation of wiring, the tube must have a minimum 0.562-inch wire entrance slot running the full length of the tube, or either stopping a minimum of 8 inches above the threaded or U-bolt secured end. Edges of slot must be supported with internal gusseting. The tube interior and slot must be free of sharp edges that may damage wiring. Provide an easily installed and removable UV stabilized seal to completely fill the wire entrance slot after installation.

995-7.4.6 Top Support Arm: The top support arm of the mounting assembly must be of one-piece solid construction, or continuous arm with support tube, and capable of holding the signal head firmly in place. Top support arms must be aluminum with a minimum ultimate tensile strength of 30 ksi and minimum yield strength of 18 ksi in accordance with ASTM B26, or be die cast with a minimum ultimate tensile strength of 27 ksi and a minimum yield strength of 24 ksi.

A one or two piece top arm is acceptable. For a one-piece top arm, use at least two 1/4-inch minimum diameter Type 316 or 304 stainless steel set screws to secure its position on the support tube. When a two-piece top arm is used, hardware required to connect components of the top arm must be 3/8-inch minimum diameter, Type 316 or 304 stainless steel.

The top support arm must have three 1/4 inch - 20 UNC-2B threaded holes to accept bolts for a tri-stud washer and gasket, or at least one imbedded or tapped and locked 5/16 inch - 18 threaded stud within the industry's standard 72-tooth serrated circular design that facilitates 5 degree increment positioning. Provide 0.090-inch thick (minimum) Type 316 or 304 stainless steel washers, nuts, and lock washers for attaching signal heads. A rubber washer, with dimensions similar to the large stainless-steel washer, must be provided for traffic signals. When mast arm clamps are used to support illuminated signs with tri-stud arrangements, a rubber washer with dimensions similar to the steel washer must also be used.

995-7.4.7 Bottom Support Arm: The bottom support arm, when not continuous arm with support tube, must be hollow to allow the routing and enclosing of all signal wiring. Bottom support arms must be aluminum with a minimum ultimate tensile strength of 30 ksi and minimum yield strength of 18 ksi in accordance with ASTM B26, or be die cast with a minimum ultimate tensile strength of 27 ksi and a minimum yield strength of 24 ksi. Plastic bottom arm

covers must be constructed of ABS with a UV inhibitor and be strong enough to contain the signal cable in the bottom arm cavity without bending during installation and warping over time.

The end of the bottom support arm that attaches to the support tube must have a 1.5-inch steel coupling imbedded and cast directly into the part during the solidification of the aluminum, or a 1-1/2 inch NPT or NPS pipe thread cut directly into the casting. For non-threaded versions, the arm must allow the support tube to sit a minimum of 2 inches into an arm pocket and be secured to the arm with minimum 5/16-inch full U-shape U-bolt to distribute the load evenly to the lower arm casting.

The end of the bottom support arm that connects to the signal must have either three equally spaced and plumb imbedded 5/16-inch Type 316 or 304 stainless steel threaded studs located in the center of the 72-tooth serrated circular design, or three 1/4 inch – 20 UNC-2B tapped holes to accept bolts for a tri-stud washer.

995-7.4.7.1 Arms with Steel Coupling: If a threaded steel coupling is imbedded into the casting, the bottom arm must be aluminum alloy 535.0-F in accordance with ASTM B26, with a minimum ultimate tensile strength of 23 ksi, meeting all standards listed in ASTM B26, including chemical composition listed in Table 1 and material mechanical properties listed in Table 2. The end of the bottom support arm must have at least two 1/4-inch diameter Type 316 or 304 stainless steel set screws to secure its position on the support tube.

995-7.4.7.2 Threaded Arms: If threads are cut directly into the casting, the bottom arm must be aluminum alloy 535.0-F in accordance with ASTM B26, with a minimum ultimate tensile strength of 35 ksi and elongation of 9.0% in a 2-inch section, meeting all standards listed in ASTM B26, including chemical composition listed in Table 1 and material mechanical properties listed in Table 2. As an alternative, the arm can be die cast in aluminum with a minimum ultimate tensile strength of 27 ksi and a minimum yield strength of 24 ksi. The end of the bottom arm must have at least two 1/4-inch minimum diameter Type 316 or 304 stainless steel set screws to secure its position on the support tube.

995-7.4.7.3 Non-threaded Arms: Lower arm must be aluminum 356 having a minimum ultimate tensile strength of 30 ksi and meeting all standards listed in ASTM B26, including chemical composition listed in Table 1 and material mechanical properties listed in Table 2. The arm must have a locator tab to receive the support tube and be secured by a U-bolt.

995-7.4.7.4 Continuous Arm Support Tube: The continuous arm support tube must be of single form construction to support the weight of any combination of signal indicators with all accessories such as backplates and visors. Continuous support tubes must be Type 316 or 304 stainless steel with a minimum ultimate tensile strength of 75 ksi and a minimum yield strength of 30 ksi in accordance with ASTM A554, or aluminum with a minimum yield strength of 25 ksi and a minimum ultimate tensile strength of 30 ksi in accordance with ASTM B221.

The continuous arm support tube attachment to the signal head must have a minimum of two 5/16-18 Type 316 or 304 stainless steel bolts, nuts and washers. A rubber seal must be provided between the support tube and signal head.

995-7.5 Span Wire Mounting Assemblies: Span wire mounting assemblies must include a span wire clamp, a hanging device such as a drop pipe, adjustable hanger, or adjustable pivotal hanger with extension bar, messenger clamp, disconnect hanger, and multi-brackets.

995-7.5.1 Span Wire Clamp: Span wire clamps must be aluminum or stainless steel and must have a minimum ultimate tensile strength of 32 ksi and minimum yield strength of 22 ksi in accordance with ASTM B28, ASTM B108, ASTM B85, or ASTM A240.

995-7.5.2 Drop Pipe: Drop pipe hangers must be galvanized 1.5-inch steel aluminum having a minimum yield strength of 35 ksi and a minimum ultimate tensile strength of 42 ksi in accordance with ASTM B221 and have NPT on each end for assembly.

995-7.5.3 Aluminum Adjustable Hanger: Aluminum adjustable hangers must be aluminum alloy 535.0-F in accordance with ASTM B26 with a minimum ultimate tensile strength of 35 ksi and elongation of 9.0% in a two-inch section, meeting the chemical composition listed in Table 1 and material mechanical properties listed in Table 2 in ASTM B26.

995-7.5.4 Stainless Steel Adjustable Hanger: Stainless steel adjustable hangers must be Type 316 or 304 stainless steel with a minimum ultimate tensile strength of 75 ksi and a minimum yield strength of 30 ksi in accordance with ASTM A276.

995-7.5.5 Aluminum Adjustable Pivotal Hanger: Aluminum pivotal hangers must be aluminum alloy 535.0-F in accordance with ASTM B26 with a minimum ultimate tensile strength of 35 ksi and elongation of 9.0% in a two-inch section, meeting the chemical composition listed in Table 1 and material mechanical properties listed in Table 2 in ASTM B26.

995-7.5.6 Stainless Steel Adjustable Pivotal Hanger: Stainless steel pivotal hangers must be either Type 316 or 304 stainless steel with a minimum ultimate tensile strength of 75 ksi and a minimum yield strength of 30 ksi in accordance with ASTM A276.

995-7.5.7 Aluminum Extension Bar: Extension bars used to extend the length of the adjustable hanger must be T6061-T6 extrusion aluminum having a minimum yield strength of 35 ksi and a minimum ultimate tensile strength of 42 ksi in accordance with ASTM B221.

995-7.5.8 Stainless Steel Extension Bar: Stainless steel extension bar used to extend the length of adjustable hangers must be Type 316 or 304 stainless steel with a minimum ultimate tensile strength of 75 ksi and a minimum yield strength of 30 ksi in accordance with ASTM A276.

995-7.5.9 Disconnect Hanger: The disconnect hanger must be supplied with the following as a minimum:

1. Wired screw type/compression terminal block and wiring rated at 600 V_{AC} Root Mean Square (rms) with 12 or 18 circuits. The terminal block must be easily accessible for connection of the field wiring. Attach the terminal block to the disconnect with Type 316 or 304 stainless steel or brass fastening hardware.

2. Weather resistant grommets in each signal cable entrance of the disconnect hanger to prevent insect and animal access and to protect the signal cable from chafing.

3. A 2-inch opening in the top of the disconnect hanger with an integral serrated area (or 1.5-inch NPT threaded top section) to interface with the hanger method employed above it.

4. A securable door that allows access to all areas of the interior. The door securing device must be Type 316 or 304 stainless steel and captive. Hinge or groove pins for the door must be Type 316, 304, 303, or 302 stainless steel.

995-7.5.10 Multi-Brackets: Top and bottom (multi) brackets used in the assembly of span wire mounted multi-directional signals must be constructed of aluminum having a minimum yield strength of 13 ksi and a minimum ultimate tensile strength of 23 ksi per ASTM B26.

Top brackets must be of one-piece hollow design, with a cross-sectional diameter of at least 1-1/2 inch I.D. for receiving signal wires. The wall thickness must be at least 3/16 inch. Each top bracket (2-way, 3-way, and 4-way) must have a two-inch diameter hole (with integral serrated boss as specified above) in the top side of the bracket for receiving a 1-1/2 inch entrance fitting. The underside of the top bracket must have a covered hole of at least three inches in diameter for the installation of the signal wires.

Bottom brackets must be of one-piece solid construction and must hold the signal heads firmly in place.

For the five-section cluster configuration, provide 3/8-inch-thick Type 316 or 304 stainless steel tri-stud washers and nylock nuts with lock washers to secure the top and lower signal sections of the cluster to the top multi bracket. Washer distortion must not occur after assembly of the five-section cluster. Multi-brackets must include all fastening hardware necessary to attach to the signal.

995-7.6 Pole (Pedestal and Post) Mounting Assemblies: All trunnions, brackets, and suspensions used in mounting vehicular and pedestrian signals to concrete, steel, aluminum, or wood poles must be an aluminum alloy cast fitting, pipe or equivalent as approved by the Engineer. The aluminum alloy must have a minimum ultimate tensile strength of 35 ksi in accordance with ASTM B221, ASTM B85, or ASTM B26.

Pole side-mount brackets used for pedestrian signals may be constructed of polycarbonate material.

995-7.7 Mounting Assemblies for Signs, Cameras, Detectors, and Other Traffic Control Devices: Mounting assemblies or assembly components used for signs, cameras, detectors, and other traffic control devices must be constructed of the same material and meet the same mechanical and chemical properties as mounting assemblies for signals.

995-7.8 Miscellaneous Mounting Components: Miscellaneous mast arm, span wire, and pole mounting components and accessories included with assemblies must meet the mechanical properties for its associated main assembly components or be listed separately on the APL. Mounting assemblies not approved with a specific primary device (such as a camera, detector, etc.), must be approved and listed separately on the APL.

995-8 Signal Priority and Preemption Systems.

995-8.1 General:

Signal priority and preemption system equipment may utilize optical, GPS, and radio frequency technologies.

995-8.2 Functional Requirements: Ensure that in-vehicle equipment operates without requiring any action from the vehicle operator or occupants once power is applied.

995-8.2.1 Security: The system must include features that secure the system and restrict its configuration and operation to authorized users and vehicles only.

995-8.2.2 Vehicle Identification: The system must be able to assign a unique identifier for each authorized vehicle. The system must be able to associate the identifier with vehicle information such as vehicle classification (e.g., fire, police, rescue, transit), owner/operator, and priority level.

995-8.2.3 Configuration and Management: The system must allow authorized local and remote users to set and read all user-programmable features and retrieve data collected by the system. The manufacturer must provide computer software required to configure, operate, and maintain the system at no additional cost to the Department.

995-8.2.4 Logging: The system installed in the field cabinet must store a record of events, including time, vehicle ID, class, priority level, and approaching direction for all vehicles detected. The log must operate on a first-in, first out (FIFO) principle with a minimum capacity of 5,000 events.

995-8.2.5 Detection Range and Accuracy: The priority and preemption system must be capable of detecting and identifying multiple authorized vehicles at various ranges up to 2,500 feet. The system must be able to determine the approaching direction of authorized vehicles. The detection range and programming of emergency (high priority) and transit signal (low priority) preemption shall be adjustable from within the traffic signal cabinet. High priority calls must override low priority calls.

The system must service preemption calls having equal priority on a first-come, first-served basis.

995-8.3 Preemption System Cabinet Electronics: The priority and preemption system must be compatible with NEMA TS 1, NEMA TS 2, Type 170, and Type 2070 traffic signal controllers and their respective cabinets.

The system must be able to provide calls to the controller via input file and detector rack. The system must include two channel or four channel detector card units. The system must include a shelf mount option.

The system must be able to provide emergency preemption (high priority) and transit signal (low priority) preemption calls to the controller. Detectors must include programmable timers that allow the operator to configure detector call extension as well as limit the length of channel output calls.

Channel outputs must deliver a constant signal while emergency vehicles are detected for high priority preemption activation. Channel outputs must deliver a pulsed output for low priority preemption activation. Inputs and outputs must be optically isolated.

995-8.3.1 Serial Interface: Ensure that the serial ports support data rates up to 115 kbps; error detection procedures utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2). Serial interface ports may utilize RJ-45 connectors, D-sub connectors, or screw terminals.

995-8.3.2 Network Interface: Ensure that LAN connections support the requirements detailed in the IEEE 802.3 Standard for 10/100 Ethernet Connections. Ensure that the connector complies with applicable TIA requirements.

995-8.4 Optical Preemption Detectors: Optical preemption detectors must respond to light impulses generated from a visible or infrared light source.

995-8.5 Intersection Radio/GPS Modules: Radio/GPS preemption systems must include radio/GPS modules that transmit a beacon signal and receive data transmitted by Radio/GPS vehicle equipment.

995-8.6 Mechanical Specifications: Ensure that every conductive contact surface or pin is gold-plated or made of a noncorrosive, conductive metal. Do not use self-tapping screws on the exterior of the assembly.

All external parts must be made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

Detector cards must include indicators for power and vehicle detection. Detector cards must include a test switch that can be used to manually generate detector calls that the system provides during normal operations.

995-8.7 Electrical Specifications: Provide equipment that operates on a nominal voltage of 120 volts V_{AC}. If the device requires operating voltages of less than 120 V_{AC}, supply the appropriate voltage converter.

995-8.8 Environmental Specifications: Ensure system electronics perform all required functions during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9. Detectors and detector connections that are exposed to the elements must be weatherproof and designed for outdoor use.

995-9 Pedestrian Detection System.

995-9.1 General: The components of the pedestrian detection system include pushbuttons, pedestrian actuation signs, electronics, wiring, and mounting hardware.

995-9.2 Standard Pedestrian Pushbutton Detector: Pushbuttons must be raised from or flush with their housings and be a minimum of 2 inches in the smallest dimension. The pushbutton must require no more than 5 pounds of force to activate. The detector must be weather-tight and tamper resistant.

995-9.2.1 Housing: The housing must be a two-piece unit consisting of a base housing and a removable cover. The housing must be cast aluminum meeting the physical characteristics and chemical content established in ASTM B26 for alloys S5A and CS72A.

The housing or adapter (saddle) must conform to the shape of a pole and provide a flush, secure fit. Saddles must be of the same material and construction as the housing. Pushbuttons for wood pole mounting must have threaded holes for 1/2-inch conduit provided in the housing top or bottom. A 3/4-inch hole with an insulated bushing shall be provided through the back of the housing. Unused openings shall be closed with a weatherproof closure and painted to match the housing.

The housing must have a powder-coat finish and painted in accordance with Military Standard MIL-PRF-24712A.

995-9.2.2 Pushbutton: The pushbutton must include a normally open, mechanical phenolic enclosed, positive-acting, spring-loaded, audible (i.e., click) snap-action switch with single pole, single throw contacts, or a Piezo driven solid state switch rated for a minimum of 50 V. The Piezo driven solid state switch, when activated, must give an audible (i.e., two-tone chirp) indication of actuation. A visual indication of actuation is optional. The visual indication must remain illuminated until the pedestrian's WALKING PERSON (symbolizing WALK) signal indication is displayed. Switch connections inside the housing must allow wiring and installation without binding. The switch must have a design life of one million operations (minimum) at rated load.

995-9.2.3 Electrical Requirements: The wiring must be No. 18 AWG stranded (minimum) with 600 V outdoor insulation rating.

995-9.3 Accessible (Audible/Tactile) Pedestrian Pushbutton Detector: The accessible pedestrian pushbutton detector must consist of all electronic control equipment, wiring, mounting hardware, pushbuttons, and pedestrian actuation signs designed to provide both a pushbutton with a raised, vibrating tactile arrow on the button as well as a variety of audible indications for differing pedestrian signal functions.

995-9.3.1 Electronic Control Equipment: The accessible pedestrian pushbutton detector must include electronic control equipment that is programmable and adjustable using a laptop computer or vendor supplied programmer. Electronic control equipment must be able to be installed within a traffic controller cabinet or within a pedestrian signal housing. Electronic control equipment installed within a traffic controller cabinet must allow the use of up to

16 pushbuttons (4 maximum per channel) with a single traffic controller cabinet. The accessible pedestrian pushbutton detector must receive timing from Walk and Don't Walk signals.

995-9.3.1.1 Audible Messages: Audible messages must be programmable. All audible messages and tones must emanate from the accessible pedestrian pushbutton housing. The accessible pedestrian pushbutton detector must utilize digital audio technology. The system shall have, at a minimum, three programmable locator tones. The accessible pedestrian pushbutton detector must have independent minimum and maximum volume limits for the Locator Tone, Walk, and Audible Beaconing features. The Wait message must only annunciate once per actuation.

995-9.3.1.2 Pushbutton locator tone: The accessible pedestrian pushbutton detector must provide independent ambient sound adjustment for the locator tone feature. The accessible pedestrian pushbutton detector must allow the locator tone to be deactivated.

995-9.3.1.3 Vibrating Pushbutton (VPB): The accessible pedestrian pushbutton detector must include a Vibrating Pushbutton (VPB). The VPB must be a single assembly containing an ADA compliant, vibro-tactile, directional arrow button, weatherproof audible speaker, and pedestrian actuation sign with optional placard Braille messages. The VPB tactile arrow must be 2 inches in length, be field adjustable to two directions, and require no more than 5 pounds of applied force to activate.

995-9.3.1.4 Conflict Monitoring: The accessible pedestrian pushbutton detector must monitor the Walk condition for conflict operation. The accessible pedestrian detector system must disable the Walk functionality if a conflict is detected.

995-9.3.1.5 Cabinet Control Unit (CCU): The accessible pedestrian pushbutton detector may include a CCU for interfacing and connecting the system. The CCU shall have labeled LED indicators for each channel operation. The CCU must reset upon loss of internal communication.

995-9.3.2 Inputs and Outputs: All inputs and outputs must use Mil-Spec Multi-pin connectors.

995-9.3.2.1 Inputs: Walk and Don’t Walk inputs must be optically isolated 80-150 volts AC/DC, 5mA max. General purpose inputs must be optically isolated 10-36 volts AC/DC, 10mA max.

995-9.3.2.2 Outputs: Outputs must be optically isolated 36 volts AC/DC peak, 300mA solid state fused contact closures. CCUs must include a normally open relay contact fault output.

995-9.3.3 Communication: The CCU must include an Ethernet interface. The CCU must have an integral web server that provides information on audible/tactile pedestrian-pushbutton detector status, access to event logs, and provides for remote Configuration of accessible pedestrian pushbutton detector system options. VPBs must include an Ethernet, serial, USB, or Bluetooth programming interface.

995-9.4 Passive Detectors: The passive detector must consist of all electronic control equipment, wiring, and mounting hardware.

995-9.4.1 General: A passive detector system uses one or more sensors and analytics hardware and software to detect the presence and direction of pedestrians and activate the traffic control device without any required action by the pedestrian.

995-9.4.2 Configuration and Management: Ensure that the passive detector is provided with software that allows local and remote configuration and monitoring. Ensure that

the system can display detection zones and detection activations overlaid on live passive detector inputs. Ensure that the passive detector allows a user to edit previously defined configuration parameters, including size, placement, and sensitivity of detection zones.

Ensure that the passive detector retains its programming in nonvolatile memory. Ensure that the detection system configuration data can be saved to a computer and restored from a saved file. Ensure that all communication addresses are user programmable.

995-9.4.3: Solid State Detection Outputs: Ensure outputs meet the requirements of NEMA TS2-2021, 6.5.2.26.

995-9.4.4: Electrical Requirements: Ensure the system operates using a nominal input voltage of 120 V_{AC}. Ensure that the system will operate with an input voltage ranging from 89 to 135 V_{AC}. If a system device requires operating voltages other than 120 V_{AC}, supply a voltage converter.

995-9.5 Electrical: All wiring must meet applicable NEC requirements. The accessible pedestrian pushbutton detector must operate using a nominal input voltage of 120 V_{AC}. If any device requires nominal input voltage of less than 120 V_{AC}, furnish the appropriate voltage converter.

Accessible pedestrian pushbutton detector control electronics that are mounted in a pedestrian signal head must be able to receive power from the Walk and Don't Walk circuits of the signal head. Control electronics shall not require more than four wires for each pushbutton connection, and no more than two wires for each controller pedestrian input. Voltage at the pushbutton shall not exceed 24 V_{AC}.

995-9.6 Mechanical: Do not use self-tapping screws on the exterior of the assembly.

Ensure that all parts are made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. Ensure that all assembly hardware, including nuts, bolts, external screws and locking washers less than 5/8-inch in diameter, are Type 304 or 316 passivated stainless steel. Stainless steel bolts, screws and studs must meet ASTM F593. Nuts must meet ASTM F594. All assembly hardware greater than or equal to 5/8-inch in diameter must be galvanized. Bolts, studs, and threaded rod must meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

Enclosures must have a NEMA 4X rating. Pushbutton housings for intersections must be black.

995-9.7 Environmental: Ensure equipment performs all required functions during and after being subjected to the environmental testing procedures described in NEMA TS2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

995-10 Traffic Controllers.

Traffic controllers must meet the industry standards in Table 995-6.

Table 995-6
Traffic Controller Standards

Device	Standard
NEMA TS2 Controller	NEMA TS2-2021
Model 2070 Controller	CALTRANS TEES, 2020
Note: All controllers must meet AASHTO/ITE/NEMA ATC 5201, v06.25.	

All controllers must provide functionality that meets or exceeds operational characteristics, including NTCIP support, as described in NEMA TS2-2021.

All controllers must:

1.Capture all mandatory event-based data elements listed in supplemental requirement SR-671-2, Supplemental Traffic Controller High Resolution Data Logging Requirements, as published on the Department's State Traffic Engineering and Operations Office website at the following URL: https://www.fdot.gov/traffic/Traf-Sys/Product-Specifications.shtm.

2. Provide and make Management Information Bases (MIBs) available for Traffic Signal Controller Broadcast Messages (TSCBM) to local agencies and FDOT that are compatible with SAE J2735.

3. Support programming of destination Internet Protocol (IP) addresses via controller front panel for interface with Roadside Units (RSU) and other devices or systems.

995-11 Traffic Cabinets.

995-11.1 General: Cabinets must be permanently marked with a label including the manufacturer's name or trademark, model/part number, and the year and month of manufacture. Place the label on the inside of the main door using a water-resistant method. The label must be visible after installation.

Painted and unpainted cabinets must meet the applicable requirements in Aluminum Cabinets, NEMA TS2-2021.

995-11.2 NEMA Traffic Signal Controller Cabinets: Provide NEMA traffic signal controller cabinets with all terminals and facilities necessary for traffic signal control meeting the following requirements:

NEMA TS1 Controller Cabinet .....NEMA TS1-1989
NEMA TS2 Controller Cabinet .....NEMA TS2-2021

995-11.2.1 Documentation: Provide four paper copies of the cabinet wiring diagram with each cabinet. The nomenclature of signal heads, vehicular movements and pedestrian movements on the wiring diagram must be in accordance with the signal operating plan.

Documentation must include a list identifying the termination points of cables used for vehicular and pedestrian signal heads, detector loop lead-ins, and pedestrian pushbutton wires.

A heavy duty, resealable plastic opaque bag must be mounted on the backside of main cabinet door for storing cabinet documentation.

995-11.2.2 Police Switches: Provide the following police switches with Type 3 and larger controller cabinets. The switches must be mounted on the police panel and identified as to their function.

1. AUTO-FLASH: When this switch is in the FLASH position, all signal indications must immediately transfer to the flashing mode. AC power shall be removed from the load switches and stop timing applied to the controller unit. When this switch is placed in the AUTO position the controller unit must operate in accordance with the appropriate specification.

2. MANUAL ON-OFF: When this switch is in the on position, a logic ground must be applied to the manual control enable input of the controller unit.

3. MANUAL JACK: Install a manual jack on the police panel. The jack must mate with a three circuit, 1/4 inch diameter phone plug. Connect the tip and ring (middle) circuits of the jack to the logic ground and the interval advance inputs of controller unit. When the manual hand cord is plugged into the jack and the pushbutton is pressed, logic ground must be connected to the interval advance input of the controller unit.

Provide a manual pushbutton with Type 3 and larger cabinets. The pushbutton cord must have a minimum length of six feet with a 1/4 inch diameter three circuit plug connected to one end and a hand held manual pushbutton at the other end. With the exception of the vehicular yellow and all red clearance intervals, a complete cycle (push-release) of the manual pushbutton shall terminate the controller unit interval that is active. Cycling the push-button during the vehicular yellow or all red clearance intervals must not terminate the timing of those intervals.

995-11.2.3 Service Switches: Service switches must be mounted on the service panel or other locations approved by the Department and identified as to their functions. Provide the following service switches with Type 3 and larger cabinets.

1. SIGNALS ON-OFF: When this switch is in the off position, AC power shall be removed from all signal heads. The SIGNALS ON-OFF switch must be connected to the control input of a contactor (displacement relay). Current supplied to the switch must not exceed five amperes (amps) total. Do not directly route the main signal head power bus and cabinet power through the service or police switches.

2. AUTO-FLASH: When this switch is in the FLASH position, all signal indications must transfer to the flashing mode in accordance with the Uniform Code Flash (UCF) requirements. AC power shall be removed from the load switches when the signal indications transfer to the flashing mode. The controller unit must operate in accordance with appropriate specifications during the flashing mode. When the switch is placed in the AUTO position, transfer from the flash mode to normal operation shall be made in accordance with UCF requirements.

3. CONTROLLER ON-OFF: When this switch is in the off position, AC power shall be removed from the controller.

4. AUX POWER ON-OFF: When this switch is in the off position, AC power shall be removed from all circuits of the cabinet except for the duplex receptacle, cabinet light and ventilation fan.

5. VEHICLE DETECTORS: A detector test switch must be provided for each phase of the controller unit. Detector test switches must include a position for normal operation (phase receives calls from detectors), a position that provides a constant call, and a position that provides a momentary call.

995-11.2.4 Doors and Locks: Provide Type 3 and larger cabinets with a hinged, rain tight and dust tight police door which allows access to the police switches and manual jack.

Locate the police door in the bottom half of the main door for Type 3 and 4 pole mount cabinets. Locate the police door in the upper half of the main door for Type 4 and larger base mount cabinets.

Hinges and hinge pins must be constructed of stainless steel and prevent the door (main or police) from sagging. Hinges for the main and police doors must be 14 gauge and be located on the right side (viewed from the front).

Type 3 and larger cabinets must be furnished with a three point draw roller latching system consisting of the following latching points:

1. Center of the cabinet (lock)
2. Top of the cabinet--controlled by the door handle
3. Bottom of the cabinet--controlled by the door handle

The latching points on the top and bottom of the cabinet must remain in the locked position until the main cabinet door lock is unlocked. The locking mechanism must be equipped with nylon rollers to secure the top and bottom of the door.

Type 3 and larger cabinets must be furnished with a door stop which retains the main door open in a 90 degree and 120 degree position.

995-11.2.5 Police and Service Panels: Provide a police service panel with Type 3 and larger cabinets. The panels may be constructed of either sheet aluminum or cast aluminum. Locate the police panel behind the police door attached to the main door. The service panel must be mounted on the back side of the police panel. The police panel must have the following minimum dimensions:

1. Height – 4 inches
2. Width – 8 inches
3. Depth – 2-1/2 inches

995-11.2.6 Ventilation: Type 1 and 2 cabinets must be vented to allow dissipation of the heat generated by the equipment housed inside the cabinet.

Type 3 and larger cabinets must have dual, UL listed, thermostatically controlled fans, rated for continuous duty with a service life of at least 3 years. Mount thermostats on the inside top of the cabinet. Thermostats must be user adjustable to allow temperature settings ranging from a minimum of 70°F to a maximum of 140°F and capable of activating the fans within plus or minus 5 degrees of the set temperature. The intake vent must be rain tight, located on the bottom half of the cabinet, and covered with a removable filter.

995-11.2.7 Shelves: Type 2 cabinets must be furnished with one shelf. Type 3 and larger cabinets must be furnished with two adjustable shelves. Shelves must be adjustable in a maximum of 2-inch increments from the top of the load panel to 12 inches from the top of the controller cabinet.

995-11.2.8 Mounting Hardware: Type 1, 2, and 3 cabinets must be supplied with hardware for attaching the top and bottom half of the cabinet onto a flat or round surface. Optional wall or pole mount hardware must be provided for mounting Type 4 cabinets in specific installations.

Type 4 cabinets must have rigid tabs attached to the bottom of the cabinet. Type 5 cabinets must have rigid brackets attached to the bottom of the cabinet. Rigid brackets and tabs must be constructed of the same material used for the cabinet.

Type 4 and larger cabinets must be provided with one of the following alternatives for fastening to a concrete base:

1. Galvanized anchor bolts, nuts, lock washers, and flat washers in accordance with ASTM A153. The anchor bolts must be at least 1/2 inch in diameter, seven inches in vertical length with at least three inch horizontal, or
2. Heavy duty machine bolt anchors, flat washers, lock washers and machine screws with at least 1/2 inch thread diameter.

995-11.2.9 Electrical: Fabricate ground busbars of copper or aluminum alloy material compatible with copper wire and provide at least two positions where No. 2 AWG stranded copper wire can be attached.

Mount a ground busbar on the side of the cabinet wall adjacent to the power panel for the connection of AC neutral wires and chassis ground wires.

If more than one ground busbar is used in a cabinet, a minimum of a No. 10 AWG copper wire must be used to interconnect them.

995-11.2.9.1 Wiring: All wiring must be laced. All conductors in the cabinet must be stranded copper.

All inputs and outputs must be terminated on terminal strips. A connector harnesses for the controller, conflict monitor, vehicle detectors, and other controller accessory equipment must be furnished and wired into the cabinet circuitry.

A vehicle detector harness or rack must be furnished with the cabinet. Terminal strip circuits must be provided for connection of the loop lead-in cable.

995-11.2.9.2 Terminal Strips: The voltage and current rating of terminal strips must be greater than the voltage and current rating of the wire which is terminated on the terminal strip.

Conductors must be terminated on terminal strips with insulated terminal lugs. A calibrated ratchet crimping tool must be used to terminate the conductor in the terminal lug.

When two or more conductors are terminated on field wiring terminal strip screws, a terminal ring lug shall be used for termination of those conductors. All terminal strip circuits must be numbered.

995-11.2.9.3 Cabinet Light and Receptacle: For Type 3 and larger cabinets, provide one or more light fixtures that illuminate the entire interior of the cabinet. All lighting fixtures must automatically turn on when the cabinet doors are opened and off when the doors are closed.

Mount and wire a three-wire 115 V_{AC} duplex receptacle in all cabinets. The receptacle must be protected by a 15A circuit breaker. Do not mount the receptacle on the main cabinet door or police and service switch panels.

995-11.2.9.4 Main Circuit Breaker: Provide a 15A circuit breaker with Type 1 and 2 cabinets, and a 30A circuit breaker with Type 3 and larger cabinets.

The main circuit breaker must turn off all power to the cabinet and shall not be used for the power switch located in the service panel.

995-11.2.9.5 Radio Interference Suppression: A radio interference suppressor must be provided in series with the AC power before it is distributed to any equipment inside the cabinet. The suppressor must provide a minimum attenuation of 50 decibels over a frequency range of 200 kHz to 75 MHz when used with normal installations and shall be hermetically sealed in a metal case.

The radio interference suppressor must have the same minimum current rating as the main circuit breaker.

The ground connection of the radio interference suppressor must be connected only to AC neutral and shall not be connected to earth ground directly.

995-11.2.9.6 Optically Isolated Inputs: The Opto common input is the common reference pin for four optically isolated inputs.

The Opto inputs are intended to provide optical isolation for pedestrian detector and remote interconnect inputs. The Opto inputs are intended to connect through external 27 K ohm, 1 W resistors for 120 V_{AC} operation and are intended for direct connection to 12 V_{AC} from the cabinet power supply for pedestrian detector applications. These inputs may alternatively be used for low-true DC applications when the Opto common pin is connected to the 24 V supply.

The Opto inputs shall provide electrical isolation of 10 megohms minimum resistance and 1000 V_{AC} RMS minimum breakdown to all connector pins except the

Opto common pin. These inputs shall exhibit nominal impedance to the Opto common pin of 5 K ohm, plus or minus 10 percent, and shall require 2.4 mA, plus or minus 10 percent, from a nominal 12 V_{AC} supply. The Opto inputs shall not recognize 3 V_{AC} RMS or less relative to the common input and recognize 6 V_{AC} RMS or more relative to the common input. Any steady state voltage applied between an Opto input and the Opto common shall not exceed 35 V_{AC} RMS. Opto inputs shall not be acknowledged when active for 25 ms or less, and shall be acknowledged when active for 50 ms or more.

995-11.2.9.7 Load Resistors: A load resistor or capacitor must be installed between the AC (common) and each signal field wiring terminal for the yellow, green and walk indication. All load resistors and capacitors must be on the front side of any panel used in the cabinet.

995-11.2.9.8 Surge Protection: Furnish surge protective devices (SPDs) for the main AC power input, all signal head field wiring terminals, interconnect cable terminals and loop lead-in cable terminals which are located in the cabinet. SPDs must be unobstructed and accessible from the front side of any panel used in the cabinet. Cabinets utilizing Din rail mounted SPDs must be grounded with a conductor to the cabinet busbar.

The SPD for the main AC power input of the cabinet must be connected on the load side of the cabinet circuit breaker.

SPDs for signal and interconnect cable field wiring terminals must meet the following:

1. Clamp the surge voltage to a level no greater than twice the peak operating voltage of the circuit being protected.
2. Withstand a surge current of 1000A with an 8 by 20 µs waveform six times (at 1 second intervals between surges) without damage to the suppressor.

SPDs for loop lead-in cables must be designed in accordance with the following requirements:

1. Protect the detector unit loop inputs against differential (between the loop lead) surges, and against common mode (between loop leads and ground) surges.
2. Clamp the surge voltage to 25 V or less when subjected to repetitive 300A surges.
3. Withstand repetitive 400A surges with an 8 by 20 µs waveform without damage.

SPDs must be installed according to the SPD manufacturer's instructions and not affect the operation of detectors. SPD leads must be kept as short as possible.

995-11.3 Type 170 Traffic Signal Controller Cabinets: Provide Type 170 traffic signal controller cabinets with all terminals and facilities necessary for traffic signal control and meeting the following requirements:

Model 332, 334 and 336S Cabinets…….CALTRANS TEES 2009

Model 336S cabinet must incorporate input surge protection mounted on a fold-down termination panel at the input file.

Model 332 cabinets must incorporate a lower input termination panel. Model 332 and 334 cabinets must be base mounted. The Model 332 cabinet must have an auxiliary MODEL 420 output file, and be configured for 8 vehicle, 4 pedestrian, and 4 overlaps.

Model 552A designation is given to Model 332 cabinet assemblies that include a swing-out EIA 19-inch rack cage.

Model 662 designation is given to Model 552A cabinets with a 66 inch height.

Cabinets must comply with figures for traffic control signals and devices available on the Department's State Traffic Engineering and Operations Office website at the following URL:
https://www.fdot.gov/traffic/Traf_Sys/Product-Specifications.shtm.

All terminals and facilities on panels must be clearly identified using permanent silk-screened text.

995-11.3.1 Base Plate and Mounting Brackets: Provide cabinets with a standard base mounting bolt pattern and a minimum of two aluminum plates welded inside for anchoring to a concrete or composite base.

995-11.3.2 Output File: Fabricate the output file using a "hard wired" harness. Printed board circuit boards are not acceptable.

995-11.3.3 Shelf: Provide an aluminum shelf with storage compartment in the rack below the controller (for remote secondary monitor/lap top computer use). The storage compartment must have telescoping drawer guides for full extension. The compartment top must have a non-slip plastic laminate attached. Provide an RS-232 connector for communications to the C2S port.

995-11.3.4 Loads: Provide dummy loads consisting of 4.7k resistors rated at five watts minimum for Greens, Peds, and Yellows. The dummy loads must be mounted on a terminal block in the rear of the output file or other approved location. Wire one side of each dummy load to AC return in a manner that allows a technician to easily attach the load to outputs from selected load switches.

995-11.3.5 Cabinet Light: Provide one or more light fixtures that illuminate the entire interior of the cabinet. All lighting fixtures must automatically turn on when the cabinet doors are opened and off when the doors are closed.

995-11.3.6 Surge Protection: Provide each cabinet with devices to protect equipment from surges. Surge protector termination panels must be attached to the cabinet rack assembly and allow sufficient space for connections, access, and surge protector replacement. AC isolation terminals must be on the same side of the cabinet as the AC service inputs. DC terminals and loop detector terminals must be installed on the opposite side of the cabinet from the AC power lines.

Surge protection for 332A cabinets must be mounted on the lower input termination panel.

Surge protection for 336S cabinets must be mounted on a custom fold down termination panel at the input file.

Under no circumstance (normal operation or short-circuit condition) shall the amperage capacity of the internal wiring and printed circuit board traces be less than the protecting threshold of circuit breakers and surge protectors provided.

995-11.3.6.1 Power Distribution Assembly Protection: The power distribution assembly (PDA) SPD must be a two-stage series/parallel device that meets or exceeds the following:

1. Maximum AC line voltage: 140 V_{AC}

2. 20 pulses of peak current, each of which will rise in 8 microseconds and fall in 20 microseconds to one-half the peak: 20kA.

3. The protector must include the following terminals:

a. Main line (AC Line first stage terminal)

b. Main Neutral (AC Neutral input terminals)

c. Equipment Line Out (AC Line second stage output terminal, 10A)

d. Equipment Neutral Out (Neutral terminal to protected equipment)

e. Ground (Earth connection)

4. The main AC line in and the equipment line outer terminals must be separated by a 200 microhenry (minimum) inductor rated to handle 10A AC service

5. The first stage clamp shall be between Main Line and ground terminals

6. The second stage clamp shall be between Equipment Line Out and Equipment Neutral

7. The protector for the first and second stage clamp must have a metal oxide varistor (MOV) or similar solid state device, rated 20 kA.

The main neutral and equipment neutral output shall be connected together internally and shall have an MOV (or similar solid state device, or gas discharge tubes) rated at 20 kA between main neutral and ground terminals.

The PDA SPD must have a peak clamp voltage of 250V at 20 kA (voltage measured between equipment line out and equipment neutral out terminals, current applied between main line and ground terminals with ground and main neutral terminals externally tied together).

The PDA SPD must have a maximum let through voltage not exceeding 500 Vpk using an 8 by 20 µs/1.2 by 50 µs; 6 kV, 3 kA surge. The SPD must either be epoxy-encapsulated in a flame retardant material or utilize thermally protected varistors and be designed for continuous service current of 10A at 120 V_{AC} RMS. Power to the Type 170E controller and to the 24V power supply must be provided from the equipment line out terminal of the PDA SPD.

995-11.3.6.2 Inductive Loop Detector Protection: Protect each inductive loop detector input channel with an external SPD that meets or exceeds the following:

1. The SPD must be a three-terminal device, two of which shall be connected across the signal inputs of the detector. The third terminal shall be connected to chassis ground to protect against common mode damage.

2.The SPD must instantly clamp differential mode surges (induced voltage across the loop detector input terminals) via a semiconductor array. The array shall be designed to appear as a very low capacitance to the detector.

3. The SPD must clamp common mode surges (induced voltage between the loop leads and ground) via solid state clamping devices.

4. Peak Surge Current

a. Differential Mode: 400A (8 by 20 µs)

b. Common Mode: 1000A (8 by 20 µs)

c. Estimated Occurrences: 500 @ 200A

5. Response Time: 40 ns

6. Input Capacitance 35 pF typical
7. Clamp Voltage
a. 30V max @ 400A (Differential Mode)
b. 30V max @1000A (Common Mode)

995-11.3.6.3 Signal Load Switch Protection: The outputs of each load switch in the output file shall be provided with a MOV connected from the AC positive field terminal to the chassis ground. The MOV must be rated 150 V_{AC} and shall be a V150LA20A (or approved equal).

995-11.3.6.4 Communication Input Protection: Each low voltage communication input must be protected as it enters the cabinet with a hybrid two-stage SPD that meets or exceeds the following:

1. The SPD must be a dual pair (four-wire) module with a double-sided, gold-plated printed circuit board connector.
2. The SPD must be installed in a ten-circuit card edge terminal block (PCB1B10A).
3. The SPD must be utilized as two independent signal pairs. The data circuits must pass through the SPD in a serial fashion.
4. Peak Surge Current
a. 10kA (8 by 20 µs)
b. Occurrences at 2000A: greater than 100
5. Response Time: less than 1 ns
6. Clamp Voltage: 30V maximum
7. Series Resistance: greater than 15 ohms per line
8. Primary Protector: 3 element gas tube
9. Secondary Protector: Solid state clamp (1.5 kW minimum)

The line side of the SPD must be connected to the communication field wires, the load side connected to the communication connector of the controller, and the ground terminal connected to chassis ground.

995-11.3.6.5 Low Voltage DC input protection: Each DC input must be protected by an SPD that meets or exceeds the following:

(a) The SPD must be a 5 terminal device. Two terminals must be connected to the line side of the low voltage pair, two terminals must be connected to the input file side, and the fifth terminal connected to chassis ground.

(b)Peak Surge Current
2 kA (8 by 20 µs)
Occurrences at peak current: 100 (typical)

(c) Response Time: 5-30 ns
(d) Shock: Must withstand 10-foot drop on concrete
(e) Clamp Voltage: 30V
(f) Series Resistance: greater than 15 ohms each conductor

995-11.3.6.6 Preemption and 115V AC signal input protection: Each preemption or AC signaling input channel must be protected by an external SPD that meets or exceeds the following requirements:

(a) The SPD must be a 3 terminal device
(b) Peak Surge Current

2000A (8 b 20 µs)

Occurrences at peak current: 25 (minimum)

(c) Response Time: less than 200 ns

(d) Peak Surge Trip Point: less than 890V nominal

995-11.3.7 Red Monitor Harness: A connector and terminal assembly designated as P20 for monitoring the absence of red, shall be an integral part of the output file. The connector must terminate, and be compatible with, the cable and connector of a Type 170 conflict monitor unit (CMU), capable of monitoring the absence of red. Provide the pin assignments of the P20 connector and terminal assembly with the cabinet plans. The P20 connector shall be physically like the cable and connector of a Type 170 CMU to prevent the absence of red cable connector from being inserted into the P20 connector 180 degrees out of alignment.

995-11.3.7.1 Programming of Unused Red Channels: Provide all cabinet assemblies with a means of programming unused red channels by installing jumpers from red monitor inputs to 115 V_{AC}. The connecting terminals for the jumpers must be accessible and located in the same terminal block for all 16 channels to assure full compatibility of all cabinet assemblies with "210 Plus" conflict monitor units.

995-11.3.8 Police Door and Panel: Provide cabinets with police doors and panels. The police panel must include text informing officers that yellow and all-red clearance intervals are timed internally.

Police switch panels must include a manual jack. The jack must mate with a three circuit, 1/4-inch diameter phone plug. Connect the tip and ring (middle) circuits of the jack to the logic ground and the interval advance inputs of controller unit. When the manual hand cord is plugged into the jack and the pushbutton is pressed, logic ground must be connected to the interval advance input of the controller unit.

The pushbutton cord must have a minimum length of six feet with a 1/4-inch diameter three circuit plug connected to one end and a hand held manual pushbutton at the other end. With the exception of the vehicular yellow and all red clearance intervals, a complete cycle (push-release) of the manual pushbutton shall terminate the controller unit interval that is active. Cycling the push-button during the vehicular yellow or all red clearance intervals must not terminate the timing of those intervals.

995-11.3.9 Technician Service Panel: Provide cabinets with a technician service panel which is mounted on the back side of the police panel (inside the main cabinet front door).

There must be two switches located on the technician service panel, clearly labeled according to the following functions:

(a) UCF – This toggle switch shall:

Place the intersection into Flashing Operation.

After meeting requirements for Flashing Operations, all power shall be removed immediately from signal load switches.

(b) Signal On/Off – This toggle switch shall disconnect all power to the signal lights through the use of a 60A contact switch placed in series with the load switch packs.

Labels must be silk screened directly on the panel.

995-11.3.10 Swing-out Rack Assembly: Provide 552-A cabinets with a pullout and rotatable rack assembly as well as an interface panel mounted on the top of the rack assembly and attached to the top shelf. The rack assembly must be constructed to house

components designed to be installed in a standard EIA 19-inch rack and shall house the Controller, Input File, Output File No. 1, PDA No. 2, and a storage compartment.

Construct the rack and slide/hinged mounting brackets so that when the rack assembly (fully loaded) can be pulled out with one hand with complete ease of operation including rotation of the assembly.

The rack assembly must have a spring-loaded latch mechanism to secure the rack assembly inside the cabinet while in the "rest" position. When pulled out of the cabinet at any point from its resting position (inside cabinet) to its full extension and rotation, the fully loaded rack assembly shall not cause any member of the assembly to bend, warp or bind. The rack must be made of one-inch square aluminum tubing with welded joints and extend and retract smoothly without noticeable friction or stress on roller guides, extension brackets, or other mechanical components. Maximum deflection of the entire rack assembly (with all equipment installed) shall not exceed 1/8 inch.

The rack assembly must have 12 technician test switches mounted to the interface frame assembly. Technician test switches must be of the momentary type and shall have eight vehicle and four pedestrian inputs.

The front of the rack assembly must be tapped with 10-30 threads with EIA universal spacing for 19-inch electrical equipment racks.

The rack assembly must be attached to the left cabinet wall through combination slide/hinged mounting brackets.

The slide/hinged mounting brackets must be fabricated from aluminum and/or stainless steel only.

Mounting bracket guides must utilize 7/8-inch stainless steel ball bearing rollers and allow extension and retraction of a loaded rack with minimal effort.

The rack assembly must be capable of rotating 210 degrees from its rest position after full extension from the cabinet.

The rack assembly must have a minimum 7/16-inch diameter aluminum rack stop rod attached to the inside left cabinet wall from the left side of the rack assembly to lock the rack into final position.

All cabinet harnesses must be long enough to maintain cabinet connections and functionality when the rack assembly is fully extended and rotated to its maximum limit. Harnesses must not bind or crimp when the rack is fully retracted, extended, or in motion.

995-11.3.11 Service Panels for 552A: The 552A cabinet must include a field service panel, auxiliary field service panel, and interface panel, all constructed of aluminum with a 1/8-inch minimum thickness. All components must be accessible from the front of the panels. Do not mount components or attach wires behind panels.

995-11.3.11.1 Field Service Panel: The field service panel must consist of terminal strips, circuit breakers, transient protection devices, load resistors, capacitors, cable tie mounts and associated wiring for making all field wiring connections. Mount the field service panel in the cabinet on the lower right exterior cabinet wall.

The field service panel must provide the necessary interconnecting junction points between the rack assembly and cabinet for the field service wires. The panel must be grouped for internal connections (jumpers) between terminals boards, wiring from the panel to the rack assembly, and wiring from the panel to the cabinet.

The field service panel wiring harness must have flexible wire covered by a flexible non-metallic conduit from the field service panel to the PDA, output file, and interface panel. The harness must have a metal clamp with a rubber grommet center attached to the field service panel to secure the harness to the panel for proper orientation of the harness with the rack assembly. Terminal strips for the panel shall be as listed below:

1. TBS1 - Terminal Block, Deadfront type, 3 position, No. 4 to No. 14 AWG wire range, 70A, 600V.
2. TBS2 - Terminal Block, Barrier, 16 position, .375 Density, 5-40 x 3/16 BH Screw, Open Bottom, Double Row, No. 16 AWG (max), 15A, 250V.
3. TBS3 - Terminal Block, Barrier, 20 position, .375 Density, 5-40 x 3/16 BH Screw, Open Bottom, Double Row, No 16 AWG (max), 15A, 250V.
4. TBS4 &TBS5 - Terminal Block, Barrier, 12 position, .438 Density, 6-32 x 1/4 BH Screw, Open Bottom, Double Row, No. 14 AWG (max), 20A, 250V.

The panel must have a main cabinet circuit breaker rated at 30A and a cabinet accessory circuit breaker rated at 15A for cabinet fans and light. Mount the circuit breakers near the back cabinet door on the panel.

The panel must include load resistors for all Walk, Green, Green Arrow, Yellow and Yellow Arrow Switch Pack outputs to prevent the conflict-voltage monitor from going into "Flash" due to a failed signal lamp. Load resistors must be 2K, 10 watt.

MOVs must be physically tied to one side of each terminal on TBS4 and TBS5 and be physically secured to the field service panel with a 6-32 screw.

995-11.3.11.2 Auxiliary Field Service Panel: The auxiliary field service panel must be mounted on the lower left interior cabinet wall and consist of a minimum of four terminal strips, 18 detector surge protectors and one pedestrian button isolation board assembly. The 18 surge protectors must be a three-terminal device, two of which are connected across the signal inputs of the detector for differential mode protection and the third terminal is grounded to protect against common mode damage. Mount the pedestrian button isolation board on the auxiliary field service panel. Terminal strips for the panel shall be Terminal Block, Barrier, 12 position, .438 Density, 6-32 x 1/4 BH Screw, Open Bottom, Double Row, No. 14 AWG (max), 20A, 250V.

Install a four-button pedestrian isolation board on the auxiliary field service panel to provide for the connection of the pedestrian buttons on phases 2, 4, 6 and 8. The board must provide electrical isolation of the field wiring to the internal cabinet wiring. The inputs to this isolation board shall be wired to terminal block TBA5 for connection to field wiring. The outputs of this board shall be carried through the harness to the input file to the proper wires that go to the interface extension panel of the controller.

The pedestrian button isolation board must include a PC board mounted on an aluminum panel with the following minimum dimensions:

Height: 2 inches
Width: 8 inches
Thickness: 1/8 to 3/16 inch

995-11.3.11.3 Interface Panel: The interface panel must consist of eight terminal strips, one telephone line suppressor and mounting fixture, two 24 V_{DC} relays and mounting fixtures, and all associated wiring for connecting the required interface equipment modules.

The front of the panel must be covered by a 1/4-inch clear plexiglass sheet, supported from the panel by four 1-1/2 inch standoffs. Secure the panels and cover using wing nuts that are removable without the use of tools. The plexiglass cover shall have 1/2-inch slot, centered over each of the terminal strips. All covers and panels must be interchangeable.

The panel wiring must provide the necessary interconnecting junction points between interface equipment cable harnesses and controller cabinet input and output signal. The panel wiring provides the functional wiring information for connecting the interface equipment in the cabinet.

The panel wiring must be grouped for internal connections (jumpers between terminal boards) as well as wiring from the controller and related cabinet functions to the terminal boards on the interface panel.

Ground wires must be No. 14 AWG wire, minimum. The internal harnesses must be located between TB1, TB2 and TB3. The external and internal wiring must be located outside of TB1 and TB4, between TB2 and TB3.

Terminal strips shall be Barrier type, .375 Density, 5-40 x 3/16 BH Screw, Open Bottom, Double Row, No. 16 AWG (max), 15A, 250V. Terminals must use nickel/cadmium plated brass screws. All terminals and facilities on panels must be clearly identified using permanent silk-screened

The K1P and K2F relays shall be 15A miniature relays with polycarbonate cover, 2 form C (CO) contact arrangement, DC coil input, socket mount, .187 inch quick connect/solder terminals, AgCdO (15A) contacts, and 24 V_{AC} coil voltage with matching socket and hold down spring. All screws on the relay socket must be brass with nickel/cadmium plating.

995-11.3.12 Storage Compartment: Mount an aluminum storage compartment in the rack assembly. The storage compartment must have telescoping drawer guides for full extension of drawer from rack assembly and have a continuous front lip for opening the compartment top for storage. The top of the compartment must be non-slip plastic laminate.

Install a communication port on the right hand side of the drawer at the front for connecting to the communications port of the controller unit via the cabinet harness.

995-11.3.13 Cabinet Rails: Provide the cabinet with four cabinet rails for mounting wiring panels and various brackets. Rails must be keyhole design with slots 2 inches on center with a top opening diameter of 5/8 inch to allow the insertion of a 5/8 inch by 1 inch carriage bolt. The rails must be approximately 1-1/2 to 2 inches wide by 1/2 inch deep. Do not use unistruts or other rails.

995-11.3.14 Electrical: Do not use printed circuit boards in any controller cabinet subsystem file or panel, including but not limited to the output file (except for the red monitor program board), service panel, interface panel, and input file.

995-11.3.14.1 Wiring: Cut all wires to the proper length and neatly laced into cables with nylon lacing. No wire shall be doubled back to take up slack. Cables in the cabinet must not interfere with the routing and connection of field wiring. Cables must be secured with nylon cable clamps, unless specified otherwise. The position of cables between the components must be such that when the door is closed, it does not press against the cables or force the cables against the various components inside the controller cabinet.

Fabricate ground busbars of a copper or aluminum alloy material compatible with copper wire and provide at least two positions where a No. 2 AWG stranded

copper wire can be attached. Mount a 6 inch ground busbar with screw terminals on the bottom flange on each side of the cabinet for connection of AC neutral wires and chassis ground. Attach a flexible ground strap between the left side ground busbar and the left side bottom rear of the rack assembly. Wiring harnesses must be covered by a flexible non-metallic conduit. Panel wire size must be a minimum of No. 18 AWG unless otherwise specified.

995-11.3.14.2 Terminals: Terminal connections must be soldered or constructed using a calibrated ratchet type crimping tool. Wiring must be traceable and without entanglement.

995-11.4 Controller Cabinet Flashing Operation: When a non-emergency flashing operation is required, the selected operation shall be performed by the UCF format. The following shall utilize UCF format:

1. Flash Switch located on the cabinet service panel
2. Time Base Coordination Flash
3. Time Switch

When flashing operation is initiated, the controller assembly shall transfer from normal operation to flashing operation only at the end of the common major street red interval, the common minor street yellow interval, or the all red interval.

UCF shall be an internal function of the controller unit and must not be inhibited by the hold command. External logic will not be allowed to provide this function.

In the event of an emergency when flashing operation is required, the controller assembly shall immediately place the intersection on flash. Emergency flash may be initiated by the following:

1. Auto/Flash Switch - A switch located on the cabinet police panel
2. Conflict-Voltage Monitor senses a conflicting indication or system error

The transfer of the controller assembly from flashing operation to normal operation shall cause the controller unit to revert to its start-up sequence unless the conflict-voltage monitor has transferred the controller assembly to flashing operation. If transferred to flashing operation by the conflict-voltage monitor, the controller assembly shall remain in flashing operation until the monitor unit is reset and automatic operation can be implemented through the normal start-up sequence.

995-11.5 Intelligent Transportation System Cabinets: The cabinet shell must conform to NEMA 3R requirements, be constructed of unpainted sheet aluminum alloy 5052-H32 with a minimum thickness of 0.125 inch and have a smooth, uniform natural aluminum finish without rivet holes, visible scratches or gouges on the outer surface. Other finishes are acceptable if approved.

The dimensions for cabinets are listed below.

Table 995-7
Cabinet Dimensions in Inches

Cabinet Type	Height	Width	Depth
340	66” - 68”	44” - 46”	26” - 28”
336	36” - 39”	24” - 26”	20’ - 22”
336S	46” - 48”	24” - 26”	22” - 24”
334	66” - 68”	24” - 26”	30” - 32”
332D	66” - 68”	48” - 50”	30” - 32”
P44	55” - 59”	44” - 46”	26” - 29”

The cabinet must be weather resistant and constructed with a crowned top to prevent standing water. All exterior cabinet welds must be gas tungsten arc (TIG) welds and all interior cabinet welds must be gas metal arc (MIG) or TIG welds. All exterior cabinet and door seams must be continuously welded and smooth and all inside and outside edges of the cabinet must be free of burrs, rounded and smoothed for safety. All welds must be neatly formed and free of cracks, blow holes and other irregularities. Use ER5356 aluminum alloy bare welding electrodes conforming to AWS A5.10 requirements for welding on aluminum. Procedures, welders and welding operators must conform to AWS requirements as contained in AWS B3.0 and C5.6 for aluminum.

The cabinet must have a lifting eye plate on both sides of the top of the cabinet for lifting and positioning it. Each lifting eye must be secured with a minimum of two bolts to the cabinet body and have a lift point opening diameter of 0.75 inch and capable of supporting a weight load of 1,000 pounds. All external bolt heads must be tamperproof.

Ground-mount cabinets must include a removable base plate and two aluminum plates, welded inside, for anchoring the cabinet. Fabricate the plates from aluminum alloy 5052-H32 a minimum of 4 inches wide by 0.125 inch thick. Provide the cabinet with four 1 inch diameter holes for anchoring.

995-11.5.1 Doors: Provide cabinets with front and rear doors, each equipped with a lock and handle. Doors must be full size, matching the height and width dimensions of the cabinet enclosure, with no fewer than three Type 4 or larger stainless steel hinges or; alternately, one full-length “piano” hinge. Hinges must be constructed of 14 gauge stainless steel with stainless steel hinge pins that are spot-welded at the top. Mount the hinges so that they cannot be removed from the door or cabinet without first opening the door. Brace the door and hinges to withstand 100 pounds per vertical foot of door height load applied to the outer edge of the door when standing open. Ensure there is no permanent deformation or impairment of any part of the door or cabinet body when the load is removed.

Door opening must provide a flange that allows the door gasket to mate with a flat surface. Include a gasket made of closed-cell material resistant to UV, weathering, elevated temperatures, and permanent deformation that is permanently bonded to the inside of each door forming a weather-tight seal when the door is closed.

995-11.5.2 Latches: Provide all cabinets with a three-point draw roller latching system for the doors. The latching system must have the following latching points.

1. Center of the cabinet (lock).
2. Top of the cabinet – controlled by the door handle.
3. Bottom of the cabinet – controlled by the door handle.

The latching points on the top and bottom of the cabinet must remain in the locked position until the main cabinet door lock is unlocked. The locking mechanism must be equipped with nylon rollers to secure the top and bottom of the door.

Provide the cabinet with a door stop that retains the main door open in a 90 degree and 120 degree position.

Outfit the doors with an industrial standard pin tumbler lock with No. 2 key, or an approved alternate, and hardware that allows the door to be secured using a padlock. Provide two keys for each cabinet lock.

995-11.5.3 Rails: Provide the cabinet with four cabinet rails that form a cage for mounting miscellaneous wiring panels and various mounting brackets. Use rails constructed of

either 0.1345 inch thick plated steel or 0.105 inch thick stainless steel that extend the length of the cabinet's sides, starting from the bottom of the enclosure. Rails must be keyhole designed with slots 2 inches on center with a top opening of 5/8 inch in diameter to allow the insertion of a 5/8 inch by 1 inch carriage bolt. Rails must be 1-1/2 to 2 inches wide by 1/2 inch deep, drilled and tapped for 10-32 screws or rack screws with EIA universal spacing. Do not use unistruts or other rail types.

995-11.5.4 Racks: The cabinet must include a standard 19-inch EIA/TIA equipment rack centered in the cabinet for mounting devices to be installed inside. Clearance in the rack between the rails must be 17-3/4 inches.

995-11.5.5 Shelf: Provide a level, rollout internal shelf with a minimum work area measuring 10 inches by 10 inches. The shelf must be capable of sustaining a constant 20 pound load and the shelf position must be adjustable.

995-11.5.6 Sunshield: Sunshields must be mounted with tamper resistant hardware to standoffs that provide an air gap of at least one inch between the exterior cabinet walls and the sunshields. Sunshield standoffs located on the roof of the cabinet must be welded to the cabinet body. Construct sunshields of 0.125 inch thick 5052-H32 aluminum sheet with corners that are rounded and smoothed for safety.

995-11.5.7 Ventilation: Provide ventilation through the use of a louvered vent at the bottom of the door. Vent depth must not exceed 0.25 inch. Provide an air filter a minimum of 192 square inches and 1 inch thick behind the vent. The filter must be removable and held firmly in place so that all intake air is filtered.

Provide a bottom trough and a spring-loaded upper clamp to hold the filter in place. The bottom trough must drain any accumulated moisture to the outside of the field cabinet.

ITS field cabinets must have dual thermostatically controlled fans, with one thermostat per fan, rated for continuous duty with a service life of at least 3 years. Mount thermostats on the inside top of the cabinet. Thermostats must be user adjustable to allow temperature settings ranging from a minimum of 70°F to a maximum of 140°F and capable of activating the fans within plus or minus 5 degrees of the set temperature. Use UL listed exhaust fans having a minimum air flow rating of 100 cubic feet per minute. Electric fan motors must have ball or roller bearings. Vent the exhaust air from openings in the roof of the field cabinet.

995-11.5.8 Electrical Requirements: All equipment must conform to applicable UL, NEC, EIA, ASTM, ANSI, and IEEE requirements. SPD's must be accessible from the front of any panel used in the cabinet. Connect the SPD for the cabinet's main AC power input on the load side of the cabinet circuit breaker. All wiring must be laced. All conductors must be stranded copper.

995-11.5.8.1 Service Panel Assembly: Provide a service panel assembly to function as the entry point for AC power to the cabinet and the location for power filtering, transient suppression and equipment grounding. Provide branch circuits, SPDs, and grounding as required for the load served by the cabinet, including ventilation fans, internal lights, electrical receptacles, etc.

995-11.5.8.2 Terminal Blocks: Terminate electrical inputs and outputs on terminal blocks. The voltage and current rating of the terminal block must be greater than the voltage and current rating of the wire fastened to it.

Terminate conductors on terminal blocks using insulated terminal lugs large enough to accommodate the conductor to be terminated. When two or more

conductors are terminated on field wiring terminal block screws, use a terminal ring lug for termination of those conductors. Number all terminal block circuits and cover the blocks with a clear insulating material to prevent inadvertent contact.

995-11.5.8.3 Ground BusBar: Fabricate ground busbars of copper or aluminum alloy material compatible with copper wire and provide at least two positions where a No. 2 AWG stranded copper wire can be attached.

Mount the ground busbar on the side of the cabinet wall adjacent to the service panel assembly for the connection of AC neutral wires and chassis ground wires. If more than one ground busbar is used in a cabinet, use a minimum of a No. 10 AWG copper wire to interconnect them. Connect the equipment rack to the ground busbar in the cabinet to maintain electrical continuity throughout the cabinet.

Follow the PANI recommendations of USDA-RUS-1751 for connections to the ground busbar. Producer (P) or electrical power and sources of stroke current connections shall be on the left end of the busbar. Absorbing (A) or grounding wires shall be connected immediately right of the P connections. Non-isolated (N) connections such as doors and vents shall be connected to the right of the A connections. Isolated (I) equipment grounds from equipment in the cabinet shall be connected on the right end of the busbar.

995-11.5.8.4 Power Distribution Assembly: Furnish a power distribution assembly that fits in the EIA 19-inch rack and provides for protection and distribution of 120 V_{AC} power.

995-11.5.8.5 Interior Lighting: Provide one or more light fixtures that illuminate the entire interior of the cabinet. All light fixtures must automatically turn on when the main cabinet door is opened and turn off when the door is closed.

995-11.5.9 Adapter Bracket: Provide an adapter bracket for pole mounted cabinets that is slotted or otherwise designed to allow banding straps to be installed to avoid pole handholes.

995-11.6 Generator and Auxiliary Power Connection: Traffic signal controller cabinets and ITS cabinets must include a generator and auxiliary power connection.

Cabinets with generator and auxiliary power connection must include provisions for the connection of an external power source, such as a portable generator, through a weatherproof, secure interface. This feature must allow authorized personnel to access, connect, and secure an external power source to the cabinet in order to restore power within five minutes of arrival time at the cabinet. A 10 AWG, 600V UL rated cable, fabricated with L5-30 connectors, a minimum of 12 feet in length, must be supplied with cabinet assemblies for field connection between generator and cabinet. The generator access door and cable entrance must include means to prevent access to insects when cable is not present.

995-11.6.1 Automatic Transfer Switch: The transfer switch must meet UL 1008 and be rated equal to or higher than the design load of the cabinet's main breaker and the generator input twist-lock connector rating. The transfer switch must provide a means of switching between normal utility power and auxiliary backup generator power. Switching time cannot exceed 250 milliseconds. Ensure that the transfer switch does not allow simultaneous active power from more than one source and does not allow generator backflow into normal utility AC circuits.

995-11.6.2 Generator Access Panel: Include a generator connection panel consisting of, at a minimum, the automatic transfer switch with a three-prong, 30 amp L5-30P twist-lock connector with recessed male contacts for generator hookup. Locate the access panel

as close as possible to the main AC circuit breaker with the bottom of the access panel no less than 24 inches above the bottom of the cabinet. Do not place the generator access panel on the main cabinet door or back door. Locate and label the transfer switch and twist lock connector on a panel easily accessible behind a weatherproof lockable exterior access door equipped with a tamper-resistant hinge. Label this access door "Generator Access Door". Provide the access door with a No. 2 lock.

The access door and cable entrance must include means to prevent access to insects when cable is not present. The generator hookup compartment must be recessed no more than six inches into the cabinet but be deep enough to allow closing and locking of the access door when the generator cable is connected. Avoid blocking access to any other equipment in the cabinet.

995-11.7 Small Equipment Enclosures: Small equipment enclosures must be a minimum NEMA 3R rated and smaller than 16 inches wide by 24 inches tall by 12 inches deep. The enclosure must be constructed of aluminum or non-metallic materials. Enclosures must include a safe means of removing power from the installed equipment for servicing and replacement, such as a switch, fuse, or breaker. Discrete markings, such as manufacturer name and model, are permitted on the outside of small enclosures.

All fasteners less than 5/8 inch exposed to the elements must be Type 304 or 316 stainless steel.

Construct aluminum enclosures of 5052 sheet aluminum alloy with a minimum thickness of 0.090 inch. Aluminum enclosures must have a uniform natural finish or be powder coat painted in accordance with AAMA-2603-02 specifications. All welds, bends, and seams must be neatly formed and free of cracks, blow holes and other irregularities. All inside and outside edges of the enclosure must be free of burrs, rivet holes, visible scratches, and gouges and have a smooth, uniform finish.

Non-metallic enclosures must be designed for outdoor use, and resist chemicals, corrosion, and ultraviolet rays.

Enclosure doors must include a vandal resistant hinge and be secured with a locking latch or a minimum of two quick-release Type 304 or 316 stainless steel latches with padlock hasps. Removal of the hinge or hinge pin must not be possible while the enclosure is closed. Provide two sets of keys with each lock.

Enclosures may be vented. Holes larger than 1/8 inch must be covered by heavy duty screen.

Post mounted enclosures must be supplied with mounting hardware for attaching the enclosure to a 4-1/2 inch (OD) aluminum post.

995-12 Traffic Controller Accessories.

995-12.1 General: Traffic controller accessories must meet the industry standards in Table 995-8 as well as the environmental requirements of those standards.

Table 995-8
Traffic Controller Accessory Standards

Device	Standard
Conflict Monitor	NEMA TS1-1989, Section 6
Malfunction Management Unit	NEMA TS2-2021, Section 4
Power Supply	NEMA TS2-2021, Section 5.3.5
Load Switch	NEMA TS2-2021, Section 6.2

Flasher	NEMA TS2-2021, Section 6.3
Bus Interface Unit	NEMA TS2-2021, Section 8
Model 206L Power Supply Unit	CALTRANS TEES, 2020, 3.4
Model 208 Monitor Unit	CALTRANS TEES, 2020, 3.5
Model 210 Monitor Unit	CALTRANS TEES, 2020, 3.6
Power Distribution Assembly	CALTRANS TEES, 2020, 6.4.3
Input File	CALTRANS TEES, 2020, 6.4.4

995-12.2 Time Switch: Ensure the time switch is a 24-hour timer which controls the daily switching operation of circuit contacts at preselected times.

Type 1 time switches must contain a single circuit contact and a solid state timer with at least 48 programmable on and off times.

Type 2 time switches must contain two circuit contacts and a solid state timer with at least three independently programmable on and off times per circuit.

Type 3 time switches must contain three circuit contacts and a solid state timer with at least three independently programmable on and off times per circuit.

995-12.2.1 Timing: Solid state timing must be accomplished by digital circuits utilizing the power line 60 Hz frequency as the normal timing reference or GPS Time Sync. Time-of-day must be settable and displayed in maximum increments of one minute.

995-12.2.2 Programming: Programming for selection of contact openings or closures must be provided in maximum increments of one minute for Types 1 through 3 time switches.

A day omit device or circuit must be provided with Types 1 through 3 time switches to omit the programmed switching operation for any combination of up to three days of the week. A positive means of indicating the day of the week must be provided with Types 1 through 3 time switches.

995-12.2.3 Reserve Power: Type 1, Type 2, and Type 3 solid state time switches must be provided with a battery backup circuit which maintains time during a power failure of up to 10 hours. The timing accuracy of battery backup circuits during a power failure must be plus or minus 0.5 seconds.

995-12.2.4 Output Circuit Contacts: Each output circuit contact must be rated for a 3A, 115 V_{AC} load. The output circuit contact must have 115 V_{AC} present when the timer turns the circuit on.

995-12.2.5 Time Switch Housing: Time switches must be enclosed in durable sheet aluminum or approved alternate housing. A terminal strip or screws must be provided with the time switch for AC power and all output circuit contacts.

995-12.3 Model 210 Conflict Monitor with Absence of Red Monitoring: The conflict monitor must be a Model 210 "PLUS" conflict monitor capable of detecting fault sequencing of signals on a per channel basis (i.e., short or absence of yellow interval and/or simultaneous dual indications). All integrated circuits having 14 pins or more must be socket mounted.

995-12.3.1 Absence of Red Monitoring: The conflict monitor must be capable of monitoring for the absence of voltage on all of the inputs of a channel (defined here as red, yellow, and green). If an output is not present on at least one input of a channel at all times, the unit shall begin timing the duration of this condition. If this condition exists for less than 700 milliseconds, the unit shall not trigger. If this condition exists for more than

1000 milliseconds, the unit shall trigger as if a conflict had occurred, causing the intersection to transfer immediately into a flashing mode, and "stop-time" to be applied to the controller. A red signal shall require the presence of a minimum of 60 $V_{AC,}$ plus or minus 10 $V_{AC,}$ to satisfy the requirements of a red indication. The red input signals shall be brought into the conflict monitor through an auxiliary connector on the monitor's front panel. Provide a similar connector on the output file, with a removable harness connecting the two. Provide an indicator on the front panel of the monitor to identify the triggering of the monitor in response to the absence of red condition.

995-13 System Control Equipment.

995-13.1 Adaptive Signal Control System: Adaptive signal control systems external to the traffic controller place detector calls to the traffic signal controller to adjust signalization timing based on measured traffic conditions independently of the traffic signal controller's preconfigured timings.

The system must interface with the traffic controller using either the Synchronous Data Link Control (SDLC) Port 1 interface and protocol or 24 V_{DC} inputs/outputs available in the traffic controller cabinet. Dynamically modifying controller configuration settings through serial communications is not allowed.

The system must include a user interface that allows the configuration of subcomponents, such as detectors and cameras, and includes remote monitoring and reporting.

The system must include the option of incorporating existing vehicle detection in addition to the primary detection used by the adaptive signal control system.

The system must not affect the normal operation of the traffic signal controller upon any failure of communication, detection, or system component.

Ensure adaptive signal control system hardware is permanently marked with manufacturer name or trademark as well as part number and serial number. Ensure that the markings are visible after installation.

995-13.2 Environmental Requirements: Ensure system control equipment performs all required functions during and after being subjected to the transients, temperature, voltage, humidity, vibration, and shock tests described in NEMA TS2-2021, 2.2.7, 2.2.8, and 2.2.9.

995-14 Internally Illuminated Signs.

995-14.1 General: Marking must be accomplished by permanently affixing an indelible label, identification plate, dot peen type stamp, casting, or metal-marking. Signs must not exceed 9 feet in width or be larger than 18.0 square feet or less in area, and must not weigh more than 144 pounds. Internally illuminated sign assemblies must be listed to the requirements of UL48 listed. Light emitting diode (LED) retrofit kits must be listed on the APL.

995-14.2 Housing: The sign housing must be constructed of continuous 5052 or 6063-T5 aluminum. All housing, corners, and door seams must be continuously welded. All exterior surfaces of the assembly must be powder-coat painted in accordance with Military Standard MIL-PRF-24712A or AAMA-2603-02. Finish must meet the requirements of ASTM D3359, ASTM D3363, and ASTM D522. Sign housings with any interior airspace must consist of a box type enclosure and separate hinged door assembly. The sign housing must include provisions to prevent water from entering the sign housing. Drain holes in the sign larger than 0.125 inch must be covered by a screen.

Signs must have removable sign faces. The sign face must be secured by a method that holds the sign face securely in place. Slide-in grooves are allowed to secure the sign face if the sign is edge lit.

The sign face must be a translucent lens constructed of 0.125-inch thick high impact strength polycarbonate or acrylic meeting UL48. Background must be translucent retroreflective sheeting coated with a transparent, pressure-sensitive adhesive film. Color must meet the criteria as detailed in Section 994. Retroreflective sheeting must meet the requirements of Section 994 and be listed on the APL.

If a door opens upward, it must have a bracket on each side to secure the door in the open position during maintenance. Doors must be permanently and continuously sealed with a foam gasket listed to UL157 to prevent the entry of water into the sign housing. Each door must be secured from opening by stainless steel rotary action draw latches as follows:

Signs of 5 feet up to 7 feet in width must have a minimum of three latches for each sign door.

Signs over 7 feet up to 9 feet in width must have a minimum of four latches for each door.

The rotary action draw latch must be captive and will not become detached or allow the door to open when the sign housing is torqued or twisted

The sign assembly must be designed and constructed to withstand 150 mph wind loads meeting the requirements of the Department's Structures Manual.

995-14.3 Luminance: The sign face must be illuminated evenly across the entire surface. Contrast ratio between the background and legend shall be at least 4:1.

995-14.3.1 Background Luminance: Minimum luminance for the legend portion of the street sign face must be no less than 87.5 lux. The luminance must be determined by averaging a minimum of seven readings. Four of the readings must be taken near the midpoint of a line that would span between the outside corners of the background and the outside corners of the legend. One reading must be taken near the midpoint of a line that would connect the top corner readings. One reading must be taken near the midpoint of a line that would connect the bottom corner readings. One reading must be taken near the vertical and horizontal midpoint of the sign.

995-14.3.2 Border and Lettering Luminance: Minimum luminance of the legend and border must be 350 lux. The luminance must be determined by averaging a minimum of 17 readings. There must be a minimum of one reading from each letter in the legend. Readings within the legend must alternate between the top, middle and bottom portion of each letter. Readings within top and bottom of the border must be perpendicular to the top and bottom readings in the background. Readings within the sides of the border must be taken parallel to the readings taken within each letter.

995-14.4 Mechanical Requirements: All assembly hardware, including nuts, bolts, external screws and locking washers less than 5/8-inch in diameter must be Type 304 or 316 passivated stainless steel. All assembly hardware greater than or equal to 5/8-inch in diameter must be galvanized. Bolts, studs, and threaded rod must meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

995-14.5 Electrical Requirements: Electrical wiring must meet NEC requirements for the light source provided. All wiring must be copper wire. All internal electrical wiring must be tight and secure. The sign must include an accessible electrical power service entrance compartment (internal or external) for connection of field wiring. External compartments must

be weather-tight. All power supplies and ballasts must be Federal Communications Commission (FCC) approved.

Electrical connections must be protected against corrosion. All signs must have provisions for an integrated photocell.

995-14.6 Environmental Requirements: The illuminated sign assembly must operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 4-2016, Section 2.

995-14.7 Warranty: Internally illuminated signs must have a manufacturer's warranty covering defects for 5 years from the date of final acceptance.

995-15 Highlighted Signs.

995-15.1 General: Highlighted signs must meet the design and functional requirements specified in this Section and Section 2A of the MUTCD. Use LEDs to highlight the sign's shape, color, or message.

Stop, Do Not Enter, Yield, and Wrong Way signs that are highlighted with LEDs must use red LEDs. All other signs must use LEDs which resemble the color of the sign background color.

995-15.2 Performance Requirements: Highlighted signs are capable of automatically dimming to reduce brightness of the LEDs at nighttime.

Highlighted signs that rely upon solar power or batteries must be capable of at least 10 days of continuous operation without the need for charging.

995-15.3 Cabinets: If the highlighted sign includes a cabinet, the cabinet must be currently listed on the APL or meet the requirements of Section 676.

995-15.4 Mechanical Requirements: All assembly hardware, including nuts, bolts, external screws and locking washers less than 5/8-inch in diameter must be Type 304 or 316 passivated stainless steel. All assembly hardware greater than or equal to 5/8-inch in diameter must be galvanized. Bolts, studs, and threaded rod shall meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

995-15.5 Electrical Requirements: Electrical wiring must meet NEC requirements for the light source provided. All wiring must be copper wire. All internal electrical wiring must be tight and secure. The sign must include an accessible electrical power service entrance compartment (internal or external) for connection of field wiring. External compartments must be weather-tight. All power supplies and ballasts must be Federal Communications Commission (FCC) approved.

Electrical connections must be protected against corrosion. All signs must have provisions for an integrated photocell.

995-15.6 Environmental Requirements: The highlighted must operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 4-2016, Section 2.

995-15.7 Warranty: Highlighted signs must have a manufacturer's warranty covering defects for 3 years from the date of final acceptance.

995-16 Dynamic Message Signs.

995-16.1 General: Dynamic message signs (DMS) must meet the requirements of NEMA TS4-2016. DMS are classified by the type of sign display and the type of mechanical construction. Use only equipment and components that meet the requirements of these minimum specifications and are listed on the APL. DMS LED retrofit kits must be listed on the APL.

995-16.1.1 Front Access DMS: Front access signs must meet the requirements of NEMA TS 4-2016, Section 3.2.6.

995-16.1.2 Walk-In DMS: Walk-in signs must meet the requirements of NEMA TS 4-2016, Section 3.2.8.

995-16.1.3 Embedded DMS: Embedded DMSs must be mounted to ground traffic signs, overhead traffic signs, or overhead cantilever traffic signs.

995-16.2 Sign Housing Requirements for all DMS: The external skin of the sign housing must be constructed of aluminum alloy 5052 H32. The interior structure must be constructed of aluminum. Internal frame connections or external skin attachments must not solely rely upon adhesive bonding or rivets.

The sign enclosure must meet the requirements of NEMA TS 4-2016, Section 3.1.1. All drain holes and other openings in the sign housing must be screened to prevent the entrance of insects and small animals.

The sign housing must comply with the fatigue resistance requirements of the AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. Design and construct the DMS unit for continuous usage of at least 20 years. The sign assembly must be designed in accordance with the Department's Structures Manual, including a wind load of 150 miles per hour.

The top of the housing shall include multiple steel lifting eyebolts or equivalent hoisting points. Hoist points are positioned such that the sign remains level when lifted. The hoist points and sign frame allow the sign to be shipped, handled, and installed without damage.

All assembly hardware, including nuts, bolts, screws, and locking washers less than 5/8-inch in diameter, must be Type 304 or 316 passivated stainless steel and meet the requirements of ASTM F593 and ASTM F594. All assembly hardware greater than or equal to 5/8-inch in diameter must be galvanized and meet the requirements of ASTM A307.

All exterior, excluding the sign face, and all interior housing surfaces must be a natural aluminum mill finish. Signs must be fabricated, welded, and inspected in accordance with the requirements of the current ANSI/AWS Structural Welding Code-Aluminum.

The sign housing must meet the requirements of NEMA TS 4-2016, Section 3.2.9 for convenience outlets.

995-16.2.1 Sign Housing for Walk-In DMS: Exterior seams and joints, except the finish coated face pieces, must be continuously welded using an inert gas welding method. Limit the number of seams on the top of the housing to a maximum of three. Stitch weld the exterior housing panel material to the internal structural members to form a unitized structure.

The exterior mounting assemblies must be fabricated from aluminum alloy 6061-T6 extrusions a minimum of 0.1875 inch thick. Include a minimum of three 6061-T6 structural aluminum Z members on the rear of the sign housing in accordance with the Standard Plans. The structural aluminum Z members must run parallel to the top and bottom of the sign housing and are each a single piece of material that spans the full width of the sign. The structural aluminum Z members must be attached to the internal framework of the sign.

The hoist points must be attached directly to structural frame members by the sign manufacturer.

Housing access must be provided through an access door that meets the requirements of NEMA TS 4-2016, Section 3.2.8.1. The access door must include a keyed tumbler lock and a door handle with a hasp for a padlock. The door must include a closed-cell neoprene gasket and stainless steel hinges.

The sign housing must meet the requirements of NEMA TS 4-2016, Section 3.2.8.3 for service lighting. If incandescent lamps are provided, they must be fully enclosed in heavy-duty shatterproof, protective fixtures. The incandescent fixtures must include aluminum housing and base, a porcelain socket, and clear glass inner cover. All removable components must be secured with set screws. If fluorescent lamps are provided, they must be fitted with shatter proof protective guards.

The sign housing must include emergency lighting that automatically illuminates the interior in the event of a power outage. Emergency lighting must be capable of operation without power for at least 90 minutes.

995-16.2.1.1 Walk-In DMS Work Area: The walk-in DMS must have a work area that meets the requirements of NEMA TS 4-2016, Section 3.2.8.2. All edges of the walkway are finished to eliminate sharp edges or protrusions.

995-16.2.2 Sign Housing for Front Access and Embedded DMS: Front access and embedded signs must meet the requirements of NEMA TS 4-2016, Section 3.2.5 and Section 3.2.6. Accessing the sign housing must not require specialized tools or excessive force to open.

995-16.2.3 Housing Face Requirements for all DMS: The sign face must meet the requirements of NEMA TS 4-2016, Section 3.1.3. All sign face surfaces are finished with a matte black coating system that meets or exceeds American Architectural Manufacturers Association (AAMA) Specification No. 2605. Submit certification that the sign face parts are coated with the prescribed thickness. Except for embedded DMS, the sign face must include a contrast border that meets the requirements of NEMA TS 4-2016, Section 3.1.6.

995-16.2.3.1 Housing Face for Walk-In DMS: No exposed fasteners are allowed on the housing face. The display modules shall be easily and rapidly removed from within the sign without disturbing adjacent display modules.

995-16.2.3.2 Housing Face for Front Access and Embedded DMS: Any exposed fasteners on the housing face must be the same color and finish as the housing face. Only captive fasteners may be used on the housing face.

995-16.2.3.3 External Fascia Panels: If the sign includes external fascia panels, they must be constructed using aluminum. Each fascia panel is finished with a matte black coating system that meets or exceeds AAMA Specification No. 2605.

995-16.2.3.4 Lens Panel Assembly: If the sign includes lens panel assemblies, they must be modular in design, removable, and interchangeable without misalignment of the lens panel and the LED pixels. The lens panel assembly must consist of an environmental shielding layer coating to protect and seal the LED and internal electronics. The coating must be a minimum 90% UV opaque. Lens panels must have a matte black coating that meets or exceeds AAMA Specification No. 2605. Lens panels must include a mask constructed of 0.080 inch minimum thickness aluminum. The mask must be perforated to provide an aperture for each pixel on the display module. The apertures must not block the LED output at the required viewing angle.

995-16.2.4 Sign Housing Ventilation System: The ventilation systems for walk-in, front-access, and embedded DMS must meet the requirements of NEMA TS 4-2016, Section 3.1.2.

Air drawn into the sign is filtered upon entry. The ventilation system must be automatically tested once each day and is able to be tested on command from remote and local control access locations. The sign must include a sensor or a sensor assembly to monitor

airflow volume to predict the need for a filter change. The ventilation system fans must possess a 100,000 hour, L10 life rating.

995-16.2.4.1 Ventilation System for Walk-In DMS: The sign includes a fail-safe ventilation subsystem that includes a snap disk thermostat that is independent of the sign controller. The thermostat is preset at 130°F. If the sign housing's interior reaches 130°F, the thermostat must override the normal ventilation system, bypassing the sign controller and turning on all fans. The fans must remain on until the internal sign housing temperature falls to 115°F.

995-16.2.5 Sign Housing Temperature Sensor: The sign controller must continuously measure and monitor the temperature sensors. The sign must blank when a critical temperature is exceeded and reports this event when polled. Ensure that remote and local computers can read all temperature measurements from the sign controller.

995-16.2.6 Sign Housing Humidity Sensor: Humidity sensors must detect from 0 to 100% relative humidity in 1% or smaller increments. Sensors must operate and survive in 0 to 100% relative humidity, and have an accuracy that is better than plus or minus 5% relative humidity. Use of a humidistat is not acceptable.

995-16.2.7 Sign Housing Photosensors: The sign must meet the requirements of NEMA TS 4-2016, Section 9.1.3. The sensors must provide accurate ambient light condition information to the sign controller for automatic light intensity adjustment. The automatic adjustment of the LED driving waveform duty cycle must occur in small enough increments that the sign's brightness changes smoothly, with no perceivable brightness change between adjacent levels. Stray headlights shining on the photoelectric sensor at night must not cause LED brightness changes.

The brightness and color of each pixel must be uniform over the sign's entire face within a 30 degree viewing angle in all lighting conditions.

995-16.3 Display Modules: Display modules manufactured by one source and fully interchangeable throughout the manufacturer's sign system shall be provided. The removal or replacement of a complete display module or LED board must be accomplished without the use of special tools.

Display modules must contain solid-state electronics needed to control pixel data and read pixel status.

The sign must have a full matrix display area as defined in NEMA TS 4-2016, Section 1.6.

995-16.3.1 LED and Pixel Specifications: LED lamps must have a minimum viewing angle of 30 degrees.

All pixels in all signs in a project, including operational support supplies, must have equal color and on-axis intensity. The sign display must meet the luminance requirements of NEMA TS 4-2016, Section 5.4, for light emitting signs connected at full power. Amber displays must produce an overall luminous intensity of at least 9200 candelas per square meter when operating at 100% intensity. Provide the LED brightness and color bins that are used in each pixel to the Engineer for approval. The LED manufacturer must demonstrate testing and binning according to the International Commission on Illumination (CIE) 127-1997 Standard.

All LEDs must operate within the LED manufacturer's recommendations for typical forward voltage, peak pulsed forward current, and other ratings. Component ratings must not be exceeded under any operating condition.

Ensure that the operational status of each pixel in the sign can be automatically tested once a day. Ensure that the pixel status test determines the functional status

of the pixel as defined by the pixel Failure Status object in National Transportation Communications for ITS Protocol (NTCIP) 1203 v02.39 and does not affect the displayed message for more than half a second.

LEDs must be individually mounted directly on a printed circuit board (PCB).

995-16.3.2 Optical, Electrical, and Mechanical Specifications for Display Modules: The display modules must be rectangular and have an identical vertical and horizontal pitch between adjacent pixels. The separation between the last column of one display module and the first column of the next module must be equal to the horizontal distance between the columns of a single display module. Full matrix DMS must have the ability to display messages with 20mm pixel pitch (resolution).

The LED circuit board must be a NEMA FR4-rated, single 0.062 inch, black PCB. No PCB shall have more than two PCB jumper wires present. All PCBs shall be finished with a solder mask and a component-identifying silk screen.

PCBs with conformal coating meeting the material requirements of IPC-CC-830 or MIL-I-46058C Military Standard, United States Department of Defense (USDOD) must be provided.

Any devices used to secure LEDs must not block air flow to the LED leads or block the LED light output at the required viewing angle. All components on the LED side of a PCB must be black.

There must be a minimum of two power supplies that are wired in a parallel configuration for redundancy. If one, or 25% of the supplies in a group, whichever is greater, completely fails, the sign shall still be supplied with enough power to run 40% of all pixels at a 100% duty cycle with an ambient operating temperature of 165°F.

The sign controller must continuously measure and monitor all LED module power supply voltages and provide the voltage readings to the TMC or a laptop computer on command.

LEDs must be protected from external environmental conditions, including moisture, snow, ice, wind, dust, dirt, and UV rays. Epoxy must not be used to encapsulate the LEDs.

995-16.3.3 Display Area for Walk-In DMS: The display area must be capable of displaying three lines with a minimum of 15 characters per line, using an 18 inch font that meets the height to width ratio and character spacing in the MUTCD, Section 2L.04, paragraphs 05, 06, and 08.

995-16.4 Characters, Fonts, and Color: The signs must be capable of displaying American Standard Code for Information Interchange (ASCII) characters 32 through 126, including all uppercase and lowercase letters, and digits 0 through 9, at any location in the message line. Submit a list of the character fonts to the Engineer for approval.

All signs must be loaded (as a factory default) with a font in accordance with or that resembles the standard font set described in NEMA TS 4-2016, Section 5.6. For signs with a pixel pitch of 35 mm or less, the sign must be loaded (as a factory default) with a font set that resembles the FHWA Series E2000 standard font.

DMS fonts must have character dimensions that meet the MUTCD, Section 2L.04, paragraph 08.

Full-color signs must display the colors prescribed in the MUTCD, Section 1A.12.

995-16.5 Main Power Supply and Energy Distribution Specifications: A nominal single-phase power line voltage of 120/240 V_{AC} must be provided. The DMS must meet the requirements of NEMA TS 4-2016, Section 10.2.

All 120 V_{AC} wiring must have an overall nonmetallic jacket or be placed in metal conduit, pull boxes, raceways, or control cabinets and installed as required by the NEC. Do not use the sign housing as a wiring raceway or control cabinet.

Surge protective devices (SPD) must be installed or incorporated in the sign system by the manufacturer to guard against lightning, transient voltage surges, and induced current. SPDs must meet or exceed the requirements of Section 996. SPDs must protect all electric power and data communication connections.

995-16.6 Uninterruptible Power Supply (UPS): Walk-in DMS must include a UPS that can be installed within the sign housing or within the ground mounted control cabinet. Front access and embedded signs must include a UPS that can be installed within the ground mounted control cabinet. The UPS system must be capable of displaying the current messages on a sign when a power outage occurs. Signs with an UPS must be able to operate on battery power and display text messages for a minimum of two hours. The system must use sealed absorbed glass mat (AGM) batteries.

995-16.7 Operational Support Supplies: Furnish the operational support supplies listed in Table 995-8. Promptly replace any of the supplies used to perform a warranty repair.

For every group of 10 or fewer DMSs provided or required, provide one set of supplies as follows:

Table 995-9
Operational Support Supplies

1 each	Sign controller and I/O board(s)
1 per DMS	LED display modules
1 each	Display power supply
1 each	Uninterruptible power supply
2 each	Surge suppression sets
1 each	Fan assembly

995-16.8 Components: All components must meet the requirements of NEMA TS 4-2016, Section 8.

995-16.8.1 Mechanical Components: All fasteners, including bolts, nuts, and washers less than 5/8 inch in diameter, must be passivated stainless steel, Type 316 or 304 and meet the requirements of ASTM F593 and ASTM F594 for corrosion resistance. All bolts and nuts 5/8 inch and over in diameter must be galvanized and meet the requirements of ASTM A307. Self-tapping screws must not be used. All parts must be fabricated from corrosion resistant materials, such as plastic, stainless steel, aluminum, or brass. Construction materials must be resistant to fungus growth and moisture deterioration. All dissimilar metals must be separated with an inert, dielectric material.

995-16.8.2 Sign Controller: The sign controller must monitor the sign in accordance with NEMA TS 4-2016, Section 9. The sign must monitor the status of any photocells, LED power supplies, humidity, and airflow sensors. Sign controllers must use fiber optic cables for data connections between the sign housing and ground-level cabinet.

The sign controller must meet the requirements of NEMA TS 4-2016, Sections 8.3 and 8.4. The sign controller must be capable of displaying a self-updating time and date message on the sign. Sign controllers within ground cabinets must be rack-mountable, designed for a standard Electronic Industries Alliance (EIA) EIA-310 19 inch rack, and includes a keypad and display.

995-16.8.3 Display System Hardware: The sign must utilize a system data interface circuit for communications between the sign controller and display modules. Except for embedded DMS, the following components must reside inside the sign housing: sign controller, display system interface circuits, display modules, power supplies, local and remote control switches, LED indicators, EIA-232 null modem cables (minimum of 4 feet long for connecting laptop computer to sign controller), and surge protective devices.

995-16.8.4 Control Cabinet: A control cabinet that meets the requirements of Section 676 shall be provided. The minimum height of the cabinet must be 46 inches.

A ground control cabinet that includes the following assemblies and components: power indicator, surge suppression on both sides of all electronics, communication interface devices, connection for a laptop computer for local control and programming, a 4 foot long cable to connect laptop computers, a workspace for a laptop computer, and duplex outlets shall be provided.

All telephone, data, control, power, and confirmation connections between the sign and ground control box, and for any required wiring harnesses and connectors shall be provided.

995-16.8.5 Sign Controller Communication Interfaces: The sign controller must have communication interfaces in accordance with NEMA TS 4-2016, Section 8.3.2. Ensure that EIA-232 serial interfaces support the following:

Table 995-10 Communication Interface Requirements	
Data Bits	7 or 8 bits
Parity	Even, Odd, or None
Number Stop Bits	1 or 2 bit

The sign controller must have a 10/100 Base TX 8P8C port or a 100 Base FX port Ethernet interface.

The TMC or a laptop computer must be able to remotely reset the sign controller.

995-16.9 Message and Status Monitoring: The DMS must provide two modes of operation: (1) remote operation, where the TMC commands and controls the sign and determines the appropriate message or test pattern; and (2) local operation, where the sign controller or a laptop computer commands and controls the sign and determines the appropriate message or test pattern.

The sign must perform the following functions:

1. Control Selection – Ensure that local or remote sign control can be selected. Ensure that there is a visual indicator on the controller that identifies whether the sign is under local or remote control.

2. Message Selection – Ensure that the sign controller can select a blank message or any one of the messages stored in the sign controller's nonvolatile memory when the control mode is set to local.

3. Message Implementation – Ensure that the sign controller can activate the selected message.

Ensure that the sign can be programmed to display a user-defined message, including a blank page, in the event of power loss.

Ensure that message additions, deletions, and sign controller changes may be made from either the remote TMC or a local laptop computer. Ensure that each font may be customized, and modifications to a font may be downloaded to the sign controller from the TMC or a laptop computer at any time without any software or hardware modifications.

Ensure that there is no perceivable flicker or ghosting of the pixels during sign erasure and writing periods.

995-16.10 TMC Communication Specification for all DMS: The sign controller must be addressable by the TMC through the Ethernet communications network using software that complies with the NTCIP 1101 base standard (formerly the NEMA TS 3.2-1996 Standard), including all amendments as published at the time of Contract letting, the NTCIP Simple Transportation Management Framework, and conforms to Compliance Level 1. The software must implement all mandatory objects in the supplemental requirement SR-700-4.1.1, Dynamic Message Sign NTCIP Requirements, as published on the Department's State Traffic Engineering and Operations Office web site at the following URL: https://www.fdot.gov/traffic/Traf-Sys/Product-Specifications.shtm.

The sign must comply with the NTCIP 1102v01.15, 2101v01.19, 2201v01.15, 2202v01.05, and 2301v02.19 Standards. The sign must comply with NTCIP 1103v02.17, Section 3.

Ensure that the controller's internal time clock can be configured to synchronize to a time server using the network time protocol (NTP). NTP synchronization frequency must be user-configurable and permit polling intervals from once per minute to once per week in one-minute increments. The controller must allow the user to define the NTP server by IP address.

995-16.11 Sign Control Software: The sign must be provided with computer software from its manufacturer that allows an operator to program, operate, exercise, diagnose, and read current status of all sign features and functions using a laptop computer. The sign control software must provide a graphical representation that visibly depicts the sign face and the current ON/OFF state of all pixels as well as allows messages to be created and displayed on the sign.

995-16.12 Environmental Requirements: The DMS must meet the requirements of NEMA TS 4-2016, Section 2.

995-16.13 Warranty: The DMS system and equipment must have a manufacturer's warranty covering defects for a minimum of 5 years from the date of final acceptance.

995-17 Electronic Display Sign.

995-17.1 General: All electronic display signs (EDS) must meet the physical display and operational requirements for warning, guide, or regulatory signs described in the MUTCD and the SHS.

The term EDS refers to a general category of electronically enhanced signs that includes electronic road signs (ERS) with warning, regulatory, or guide legends; electronic speed feedback signs (ESFS); and blank-out signs (BOS).

EDS must allow attachment to vertical and horizontal support structures as part of a single or double sign post configuration. Bolts must be used for load bearing attachments.

995-17.2 Requirements Common to all EDS: All EDS must be designed to withstand the loads defined in the Department's Structures Manual without deformation or damage. EDS, other than BOS, must provide an option to include flashing beacons. Printed circuit boards must be protected with conformal coating. Housings that contain electronics must be constructed of aluminum alloy sheet a minimum of .090 inch thick. Welding used during the construction of EDS must be accordance with Section 965.

Signs included on the APL will be designated with a size and type category and may be listed with restrictions, such as "requires District Traffic Operations Engineer approval", "school zones only", or "low speed only".

995-17.2.1 Electronic Display Sign with Static Sign Panel: EDS that include both a static sign panel and dynamic display may be a modular system comprised of a static sign panel with an attached electronic display. Static sign panels must meet the Department's requirements for highway signing found in this Section.

995-17.2.2 Electronic Display: Electronic displays must appear completely blank (dark) when not energized. No phantom characters or graphics will be allowed under any ambient light conditions.

995-17.2.3 Housing: The housing must protect and seal the dynamic display and other internal electronics. Any polycarbonate material used on the sign face must be a minimum 90% UV opaque and resistant to fading and yellowing. The housing must be NEMA 3R rated and prevent unauthorized access. The housing must include weather tight cable entry or connection points for any required power or data connections.

995-17.2.4 Cabinet: Any equipment cabinets provided with the EDS must be listed on the APL.

995-17.2.5 Optical, Electrical, and Mechanical Specifications for Display Modules: All LEDs must operate within the LED manufacturer's recommendations for typical forward voltage, peak pulsed forward current, and other ratings. Component ratings must not be exceeded under any operating conditions.

995-17.2.6 LED and Pixel Specifications: All LEDs used in the display must have a wavelength output that varies no more than plus or minus two nanometers from the specified peak wavelength. The display and LED pixel cone of vision must be a minimum of 15 degrees (centered around the optical axis, or zero point, of the pixel). The cone perimeter is defined by the point where light output intensity is 50% of the intensity measured at the zero point of the pixel. For all colors other than white, the sign display must produce an overall luminous intensity of at least 9200 candelas per square meter when operating at 100% intensity. For white or full color matrix displays, the sign display must produce white with an overall luminous intensity of at least 12,400 candelas per square meter when operating at 100% intensity. Submit documentation that indicates the LED brightness and color bins that are used in each pixel. LEDs must be individually mounted on a PCB and must be able to be removed and replaced using conventional electronic repair methods. Encapsulated LEDs within a pixel are not allowed. ERS LEDs must be arranged and powered in a manner that maintains a discernible message in the event of a single LED or pixel failure.

995-17.2.7 Character Size, Fonts, and Graphics: The minimum numeral and letter size of the electronic display must meet or exceed the numeral and letter sizes prescribed in

the MUTCD and the SHS. Fonts and graphics must mimic the characteristics of fonts and graphics defined in the MUTCD and SHS.

995-17.2.8 Electronic Display Controller: Any electronic display controller required for the operation of the EDS shall be housed within the sign and be equipped with a security lockout feature to prevent unauthorized use. The controller shall have the capability to provide a stipulated default message upon loss of controller function. A blank message is acceptable.

995-17.2.9 Communication: The electronic display controller shall possess a minimum of one serial, Ethernet, USB, or Bluetooth interface with the ability to connect to a laptop computer. The serial data interface shall support multiple data rates from 9,600 bps to 115,200 bps.

995-17.2.10 Configuration and Management: Ensure that the sign is provided with computer software from its manufacturer that allows a user to program, operate, exercise, diagnose, and read current status of all sign features and functions using a laptop. Configuration and management functions must be password protected.

995-17.2.11 Operation and Performance: Ensure that the EDS is visible from a distance of at least 1/4 mile and legible from a distance of 400 feet for applications on roads with a speed limit less than 45 mph and visible from a distance of at least 1/2 mile and legible from a distance of at least 650 feet for roads with speed limits 45 mph or higher. In both cases, the requirements must be met under both day and night conditions.

The electronic display shall automatically adjust brightness for day and night operation. The EDS must be equipped with a light sensor that accurately measures ambient light level conditions at the sign location. The EDS must automatically adjust LED intensity based on the ambient light conditions in small enough increments that the sign's brightness changes smoothly, with no perceivable brightness change between adjacent levels. Stray headlights shining on the photoelectric sensor at night must not cause LED brightness changes.

Flashing messages must not exceed 150 flashes per minute.

995-17.2.12 Mechanical Specifications: EDS mounting provisions and mounting hardware must accommodate sign weight and wind loading requirements of the Department's Structures Manual. BOS must be designed to accommodate overhead attachment using a tri-stud signal hanger. Multiple tri-stud attachment points may be used to meet weight and wind loading requirements. Tri-stud attachment points must be weather-tight and structurally reinforced.

995-17.2.13 Fasteners and Attachment Hardware: Ensure that all assembly hardware, including nuts, bolts, external screws and locking washers less than 5/8 inch in diameter, are Type 304 or 316 passivated stainless steel. Stainless steel bolts, screws and studs must meet ASTM F593. Nuts must meet ASTM F594. All assembly hardware greater than or equal to 5/8 inch in diameter must be galvanized. Bolts, studs, and threaded rod must meet ASTM A307. Structural bolts must meet ASTM F3125, Grade A325.

995-17.2.14 Electrical Specifications: All power inputs must be fuse and reverse polarity protected. All EDS must be able to recover from power loss and return to their operational state without user intervention.

995-17.2.14.1 Solar Power: Solar powered signs must be capable of fully autonomous operation 24 hours per day, 365 days per year. Batteries must be a standard 12 volt deep cycle battery suitable for the application and operating environment. Flooded lead-acid batteries are prohibited.

Batteries must be capable of providing 10 days of continuous operation without sunlight. Charging system must use a solar charge controller with temperature compensation. The system must provide for automatic battery charging, overcharge protection, and have indications that display current status and faults.

995-17.2.14.2 AC Power: Fluctuations in line voltage must have no visible effect on the appearance of the display.

995-17.2.15 Environmental Requirements: The EDS assembly must operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 4-2016, Section 2. Fog, frost, or condensation must not form within the dynamic portion of the sign. Electronics must meet FCC Title 47, Subpart B Section 15.

995-17.2.16 Warranty: The EDS systems and equipment furnished must have a manufacturer's warranty covering defects for a minimum of 3 years from the date of final acceptance.

995-17.3 Electronic Warning Signs: EWS must include a secure wireless connection to communicate with a nearby laptop.

995-17.3.1 EWS Foreground/Background Colors: If a black background is used on the changeable electronic display, the color used for the legend must match the background color that would be used on a standard sign for that type of legend, in accordance with the MUTCD. Black EWS display backgrounds must be flat black (FED-STD-595-37038) with a reflectance value not exceeding 25%. EWS must utilize yellow LEDs with a peak wavelength of either 585 or 590 nanometers. EWS must have a minimum one-inch contrasting margin around illuminated characters or graphics.

995-17.3.2 Speed Detector: EWS that detect or display the speed of approaching vehicles must be programmable for the posted speed limit and the maximum speed to display. When the detected speed exceeds the maximum programmed speed (high speed cut-off) threshold, the display must automatically blank. Alternately, the display may show an alert message such as "SLOW DOWN" when speeds above the maximum programmed speed threshold are detected.

The EWS must detect when the posted speed is exceeded by one mph and then activate the alert. When the alert is activated, the display shall be able to flash. When no advancing traffic is detected, the display must be blank. The speed detector must not activate alerts for vehicles outside the display cone of vision.

The speed detector must meet the requirements of FCC Title 47, Part 90 and not require an FCC operating license. The speed detector must operate on 10.8 to 16.6 V_{DC} and draw less than three amperes. The EWS must monitor and display the speed of approaching traffic only. The EWS detector must be able to accurately detect and determine the speed of approaching vehicles. The EWS must be capable of measuring and displaying speeds of approaching traffic only between 10 and 99 mph with an accuracy of plus or minus one mph, 1,000 feet in advance of the sign.

995-17.4 Electronic Regulatory Signs: Display modules for ERS must have a minimum two-inch contrasting margin around digits, text, or graphics. ERS must utilize LED technology for the dynamic display.

995-17.4.1 ERS Battery Backup System: AC powered signs must include a battery backup system that maintains full operation of the sign for a minimum of two hours in the event of utility power loss. Operation on battery backup can have no visible effect on the appearance of the display.

995-17.4.2 Variable Speed Limit Signs: Variable speed limit signs (VSLS) must be able to display speed limits from 5-70 mph in five mph increments and mimic the physical appearance of a static regulatory speed limit sign as shown in the MUTCD and SHS. VSLS must use black characters on a white background. VSLS must log the time and date of any speed limit change to internal non-volatile memory. The log must be able to record a minimum of 1,000 events in a first-in, first-out fashion.

995-17.4.2.1 VSLS Controller Communications: VSLS must be equipped with a sign controller that includes a minimum of one Ethernet 10/100 Base TX 8P8C port.

995-17.4.2.2 Configuration and Management Requirements for VSLS: VSLS must support remote management from a TMC and local management using a laptop computer. Remote and local computers must be able to reset VSLS sign controller. VSLS must log and report status, errors, and failures, including data transmission errors, receipt of invalid data, communication failure recoveries, power failures, power recoveries, display errors, fan and airflow status, temperature status, power supply status, and information on the operational status of the temperature, photocell, airflow, humidity, and LED power supply sensors.

The sign controller must be addressable through an Ethernet communication network using software that complies with the NTCIP requirements published online by the Department's Transportation Traffic Engineering Research Laboratory (TERL) at: https://www.fdot.gov/traffic/. The sign must implement any NTCIP standards required to achieve interoperability and interchangeability. Any additional objects implemented by the software must not interfere with the standard operation of any mandatory objects. VSLS must be compatible with the Department's SunGuide® software.

995-17.5 Blank-Out Signs: BOS must have a black exterior finish (FED-STD-595-37038) with a reflectance value not exceeding 25%. Overhead BOS must include a visor.

995-17.6 Electronic Speed Feedback Signs: The ESFS display background must be flat black (FED-STD-595-37038) with a reflectance value not exceeding 25%. ESFS must utilize amber LEDs with a peak wavelength of 590 nanometers. ESFS shall have a minimum one-inch contrasting margin around illuminated characters or graphics.

995-17.6.1 Speed Detector: The ESFS must be programmable for the posted speed limit and the maximum speed to display**.** When the detected speed exceeds the maximum programmed speed (high speed cut-off) threshold, the display must automatically blank. Alternately, the display may show an alert message such as "SLOW DOWN" when speeds above the maximum programmed speed threshold are detected. The ESFS must detect when the posted speed is exceeded by one mph and then activate the alert. When the alert is activated, the display must flash at a rate of 50 to 60 cycles per minute. When no advancing traffic is detected, the display must be blank. The speed detector must not activate alerts or display speeds for vehicles outside the display's cone of vision. The ESFS must meet the requirements of FCC Part 90 and not require an FCC operating license. The speed detector must operate on 10.8 to 16.6 V_{DC}. The ESFS must be capable of measuring speeds of approaching traffic between 10 and 99 mph with an accuracy of plus or minus one mph, 1,000 feet in advance of the sign.

995-18 Sign Beacon.

995-18.1 General: Flashing beacon assemblies incorporating a circular traffic signal must meet the design and functional requirements set forth in MUTCD Chapter 4L. All circular beacons must have a minimum nominal diameter of 12 inches and meet the requirements of Section 650. All beacons must use a LED light source.

995-18.1.1 School Zone Beacon: Beacons designed for use with school zone signing must include a means of calendar scheduling to program days and times of operation.

995-18.1.2 Vehicle Activated Beacon: Vehicle activated beacons must utilize a vehicle detection system listed on the APL.

995-18.1.3 Pedestrian Activated Beacon: Pedestrian activated beacons must utilize a pedestrian detector listed on the APL.

995-18.2 Cabinets, Housings, and Hardware: Flashing beacon cabinets must be currently listed on the APL or meet the requirements of Section 676.

All housings, other than pole-mounted cabinets, must be powder coated dull black (FED-STD-595-37038) with a reflectance value not exceeding 25% as measured by ASTM E1347. Cabinets and housings must prevent unauthorized access.

Flashing beacon assemblies must allow installation on 4-1/2 inch outer diameter posts.

Ensure all exposed assembly hardware including nuts, bolts, screws, and locking washers less than 5/8 inch in diameter, is Type 304 or 316 passivated stainless steel and meets the requirements of ASTM F593 and ASTM F594. All assembly hardware greater than or equal to 5/8 inch in diameter must be galvanized and meet the requirements of ASTM A307.

995-18.3 Electrical Specifications: Provide equipment that operates on solar power or a nominal voltage of 120 V_{AC}. If the device requires operating voltages of less than 120 V_{AC}, supply the appropriate voltage converter. Solar powered beacon systems must be designed to provide 10 days of continuous operation without sunlight and must automatically charge batteries and prevent overcharging and over-discharging. Solar powered systems must include a charge indicator.

995-18.4 Environmental Specifications: All electronic assemblies must operate as specified during and after being subjected to the transients, temperature, voltage, humidity, vibration, and shock tests described in NEMA TS 4-2016, Section 2. All electronic equipment must comply with FCC Title 47 Subpart B Section 15.

995-18.5 Warranty: Ensure all flashing beacons have a manufacturer's warranty covering defects for a minimum of 3 years from the date of final acceptance. Ensure the manufacturer will furnish replacements for any part or equipment found to be defective during the warranty period at no cost to the Department or maintaining agency within 30 calendar days of notification.

995-19 In-Street Signs.

995-19.1 General: In-Street signs consist of the R1 6a or R1 6c In Street Pedestrian Crossing Sign assemblies including the sign base.

995-19.2 Materials: The sign assembly includes the vertical panel, retroreflective sign sheeting, a rebounding boot support, and a base. The vertical panel is bolted to a flexible boot which is fastened to a plastic, recycled PVC, or rubber base. The sign assembly shall contain no upright metal parts.

The vertical panel shall yield (bend) fully upon vehicle impact, then return to vertical position plus or minus 10 degrees with no delaminating. The face of the vertical panel shall resist twisting and remain oriented to the installed direction after vehicle impact. The vertical panel shall not split, crack, break, or separate from base. Use only UV stabilized, ozone and hydrocarbon resistant outdoor-grade thermoplastic polymer, polycarbonate, recycled PVC, or HDPE materials. UV stabilization testing shall be in accordance with ASTM D1435.

Use Type XI fluorescent yellow-green retroreflective sign sheeting meeting the requirements of Section 994 on both sides of the vertical panel. The surface of the panel shall be smooth and free of defects, suitable for adherence of appropriate retroreflective sheeting.

995-19.2.1 Base:

995-19.2.1.1 Sign Base (Fixed): The base shall be constructed with high-impact materials using ozone and hydrocarbon resistant outdoor grade thermoplastic polymer, polycarbonate, or HDPE materials meeting the general provisions for all In-Street sign bases.

995-19.2.1.2 Sign Base (Portable): Portable base assemblies shall consist of a lightweight plastic, recycled PVC, or rubber material that may be easily moved or relocated by a single person.

995-19.2.1.3 Color: Sign bases shall be either black, or the same color as the adjacent pavement marking.

995-19.2.2 Approved Product List (APL): In addition to the APL requirements of 995-1.2, provide the following:

1. Product Drawings, which at a minimum includes:
    a. Model Number
    b. Allowable sign panel size and substrate
    c. Dimensions of sign base and mounting heights
2. Crash Test Reports demonstrating MASH compliance
3. All FHWA Eligibility Letters
4. When requested, submit product sample

995-19.3 Vertical Panel Messages: Fabricate vertical panel messages in accordance with Section 994. Vertical panels of 9 inches in width x 27 inches in height or 12 inches x 36 inches are acceptable. See Standard Plans Section 700-102

995-19.4 Connection Method: Products will be categorized as either Fixed Base or Portable. Fixed base will be installed in accordance with the manufacturer's instructions. Portable base will be limited to temporary applications at school crossings where a crossing guard is present during school arrival and departure times or when children are present.

SECTION 996

INTELLIGENT TRANSPORTATION SYSTEM DEVICE MATERIALS

996-1 Description.

996-1.1 General: This Section governs the requirements for all permanent intelligent transportation system devices. All equipment shall be permanently marked with manufacturer name or trademark, part number, and date of manufacture or serial number.

996-1.2 Product Acceptance: All specified products shall be items listed on the Department's Approved Product List (APL), unless otherwise noted below. Manufacturers seeking evaluation of products for inclusion on the APL shall submit an application in accordance with Section 6 and include the following documentation. A separate application must be submitted for each product to be evaluated, showing that the product meets the applicable requirements.

Table 996-1

Documentation	Requirements
Assembly and Installation Instructions	Include any surface preparations, assembly/installation instructions, operation manual, troubleshooting guides, and repair procedures.
Independent Laboratory Test Results	Product meets requirements of this Section.
Product Label Photo	Labeling shows the manufacturer's name, trademark, and product model number/name. Label shows the date of manufacture and/or the manufacturer's batch number. Additional label requirements, as listed within this Section.
Product Photo	Displays the significant features of the product as required in this section.
Compliance Matrix	Include completed compliance matrix at https://www.fdot.gov/traffic/traf-sys/product-specifications.shtm
Manufacturer's Product Specifications	Include product specifications showing electrical requirements, voltages, etc.
Product Drawings or Cut Sheet	Show mounting points, mechanical details, block diagrams, schematics, etc.
Parts List	List major parts and field serviceable components.

996-1.3 Abbreviations: The following abbreviations are used in this Section:

Alternating Current (AC)
Closed Circuit Television (CCTV)
Direct Current (DC)
Electronic Industries Alliance (EIA)
Hypertext Transfer Protocol (HTTP)
Internet Protocol (IP)
Local Area Network (LAN)

Network Time Protocol (NTP)
Pan, Tilt, Zoom (PTZ)
Telecommunications Industry Association (TIA)
Uniform Resource Locator (URL)
Ultraviolet (UV)

996-2 Video Equipment.

996-2.1 General: All CCTV camera equipment shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6. All parts shall be constructed of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements shall be Type 304 or 316 passivated stainless steel.

996-2.2 CCTV Camera:

996-2.2.1 Camera: CCTV cameras shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216. CCTV cameras shall be compatible with the current version of the Department's SunGuide® software system. Camera types include dome pan-tilt-zoom (PTZ), external positioner-PTZ, and fixed. Video types include analog and internet protocol (IP). Analog camera shall produce a National Television System Committee (NTSC) composite video output of 1V peak-to-peak (Vp-p) at 75 ohms with a minimum resolution of 470 horizontal and 350 vertical TV lines.

Analog and IP cameras shall provide the following features and capabilities:

1. Day (color)/night (monochrome) switchover.
2. Manual and automatic focus.
3. Automatic iris.
4. Ability to produce clear, detailed, and usable video images of the areas, objects, and other subjects visible from a roadside CCTV field site. Video produced by the camera is true, accurate, distortion free, and free from transfer smear, oversaturation, and any other image defect that negatively impacts image quality under all lighting and weather conditions in both color and monochrome modes.
5. User-selectable automatic gain control (AGC) that is peak-average adjustable to 28 dB.
6. A minimum signal-to-noise ratio of 50 dB.
7. Automatic color balance that references the white areas of the scene through the lens.
8. An automatic electronic shutter that is user selectable from 1/60 to 1/10,000 of a second.
9. PTZ cameras shall include a minimum 10x digital zoom.
10. PTZ cameras shall include programmable azimuth and compass display with ability to display pan and tilt position with a 1 degree resolution.

CCTV cameras shall provide titling and masking features including, but not limited to, programmable camera title, programmable preset titles for each preset position, and programmable privacy zones. Programmable titles shall allow a minimum of 18 characters per line.

996-2.2.2 Lens: Standard definition PTZ cameras shall include a minimum 22x motorized optical zoom lens with automatic iris. High definition PTZ cameras shall include a minimum 18x motorized optical zoom lens with automatic iris. Fixed cameras shall have a 3-9 mm varifocal lens with automatic iris unless otherwise shown in the Plans. The lens shall have a maximum aperture of at least f/1.6 and the depth of field shall provide a clear image of roadside areas under all lighting conditions.

996-2.2.3 Pan/Tilt Mechanism for Dome-Type Cameras: Dome PTZ cameras shall meet the following requirements:

1. Have an integrated pan/tilt mechanism that provides 360 degree continuous pan with a minimum 90 degree tilt range (i.e., 0 degrees to minus 90 degrees);
2. Provide for variable speed control;
3. Have a preset position return accuracy of plus or minus 0.36 degree, or less than 0.10% or better;
4. Support a minimum of 64 presets; support a minimum of one tour with a minimum of 32 presets; and support a minimum of eight programmable blackout zones.

The positioner within the dome-type CCTV camera shall have a minimum automatic pan speed of 240 degrees per second to a preset camera position, a maximum manual pan speed of 80 degrees per second minimum and a maximum manual tilt speed of 40 degrees per second minimum.

996-2.2.4 Pan/Tilt Mechanism for External Positioner-Type Cameras: External positioner-type CCTV cameras shall include a pan/tilt mechanism that provides 360 degree continuous pan with a minimum 115 degree tilt range (i.e., minus 90 to plus 25 degrees), provide for variable speed control, have a preset position return accuracy of plus or minus 0.36 degree or less than 0.10% or better, and support a minimum of 32 presets.

996-2.2.5 Communication: Analog CCTV cameras shall support the National Transportation Communications for ITS Protocol (NTCIP) 1205 v1.08. The camera shall communicate with other devices using Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA)-232 or TIA-422 at a rate of 9600 bps, transmission control protocol (TCP)/IP, or user datagram protocol (UDP)/IP. All CCTV cameras shall provide for remote firmware upgrades via the communication interface.

IP cameras shall support either NTCIP 1205v01.08 or the Open Network Video Interface Forum (ONVIF) Core, Streaming, and Media Service specifications.

The camera shall implement all objects, operations, and commands required by SR-682-1.2.1-01, Supplemental CCTV Camera NTCIP and ONVIF Requirements, as published on the Department's State Traffic Engineering and Operations Office website at the following URL: https://www.fdot.gov/traffic/Traf_Sys/Product-Specifications.shtm.

996-2.2.6 Electrical Requirements: Cameras shall operate on a nominal voltage of 120 V_{AC}. Provide an appropriate voltage converter for devices that require operating voltages of less than 120 V_{AC}.

996-2.2.7 Mechanical Requirements: Camera housings shall include a sunshield to reduce the solar heating of the camera. The total weight of dome-type CCTV cameras (including the housing, sunshield, and all internal components) shall be less than 17.0 lbs. The lower dome of the camera housing shall be constructed of distortion free clear plastic.

Pressurized dome-type housings shall be capable of pressurization at 5 psi using dry nitrogen, have a low-pressure alarm feature, and a NEMA 4X/IP-67 rating.

If a non-pressurized dome-type housing enclosure is used, the unit shall be vented with a thermostat-controlled heater and blower. The non-pressurized enclosure shall have a NEMA 4/IP-66 rating.

The total weight of external positioner-type CCTV cameras (including housing, sunshield, all internal components, and external pan and tilt mechanism) shall be less than 35 lb.

996-2.2.8 Environmental Requirements: CCTV cameras shall perform all required functions during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

All CCTV cameras, mounting hardware, and any other camera-related material that is exposed to the environment shall be designed for 150 mph wind speeds and meet the requirements of the Department's Structures Manual.

996-2.2.9 Additional Requirements for IP Cameras:

996-2.2.9.1 Video Encoding: The camera shall utilize the Moving Picture Experts Group's MPEG4 part 10 (H.264) video compression technology in accordance with the ISO and IEC requirements detailed in the ISO/IEC 14496-10:2009 Standard.

Cameras shall establish unicast and multicast sessions using the Real-Time Streaming Protocol (RTSP). The encoded video shall transmit using programmable bit rates and the camera supports, at a minimum, a fixed bit rate mode.

996-2.2.9.2 Encoded Video Requirements: The camera's encoded video shall support resolutions that include; but are not limited to, those defined in Table 996-1. The camera shall deliver color and monochrome video at 30 frames per second (fps), regardless of resolution.

Table 996-1
Minimum Resolution Requirements

Format	Vertical Resolutions
H.264	240, 480
Note: The resolutions attained depend on the data transmission rate.	

996-2.2.9.3 Network Interface: The camera's Local Area Network (LAN) connection shall support the requirements detailed in the IEEE 802.3 Standard for 10/100 Ethernet connections. The camera shall have a minimum of one 10/100 Base-TX connection Ethernet port.

Unshielded twisted pair/shielded twisted pair network cables shall be compliant with the EIA/TIA-568-B Standard. The network communication shall conform to TCP, UDP, Version 4 of the IP, RTSP, and Version 2 of the Internet Group Multicast Protocol (IGMP), at a minimum. If the camera supports NTCIP, then the camera shall be able to be controlled via TCP/IP or UDP/IP.

996-2.2.9.4 Configuration Management: The camera shall support local and remote configuration and management via serial login, telnet login, or a web-based interface. Configuration and management functions shall include access to all user-programmable features including, but not limited to, network configuration, video settings, device monitoring, and security functions.

996-2.3 Video Display Control System:

996-2.3.1 Display Control System: The video display control system shall allow the operator to control and manage the display of video and computer-generated graphics on the display equipment connected to the system as well as provide selection and switching of multiple sources for display, including video streams available on the Traffic Management Center (TMC) Ethernet network. The display control system shall also allow for operator control of all displays from the same workstation that is used for the SunGuide® operator interface. The video display control system shall decode and display all video streams produced by encoders listed on the APL.

The video display control system simultaneously displays a minimum of 32 video windows, each containing streaming video at a minimum resolution of 720 pixels by 480 pixels and frame rate of 30 fps. The system shall allow any display window to be sized from 1/32 of the total display area up to the total display area, and any size in between.

The video display control system hardware shall be designed to be rack mounted and secured in an EIA 19 inch equipment rack. Any system incorporating Personal Computer (PC) hardware shall use current microprocessor technology and commercial, off-the-shelf components, including RAM, hard disk drives, and network interface cards sufficient to provide the functional requirements of the system.

The video display control system shall be expandable and scalable to support any combination of inputs and outputs.

The video display control system shall have a minimum configuration of 4 composite video inputs, 4 component (red, green, and blue (RGB) video inputs, and 4 High-Definition Multimedia Interface (HDMI) inputs as well as network connections, decoders, and associated hardware and software required to display 32 inputs simultaneously at a minimum resolution of 720 pixels by 480 pixels and a frame rate of 30 fps.

The video display control system shall have a minimum configuration of 4 composite video outputs, 2 component (RGB video outputs), and 4 HDMI outputs.

996-2.3.2 Display Control Software: The display control software shall allow multiple operators to control all features and functions of the video display control system. These features and functions include, but are not limited to, selection of video sources for display; adjusting the size, location, and layout of video and other graphic information the system displays; and system configuration and setup. The control software shall be able to operate a video wall composed of multiple display components as though it were a single, high-resolution display.

The display control software shall include a non-proprietary Software Development Kit (SDK) including, but not limited to, an Application Programming Interface (API) that describes interfaces and protocols which can be used to integrate system features and functions with third-party applications.

996-2.3.3 Controller Inputs and Outputs: The video display control system shall support and display a variety of video and data inputs simultaneously, including composite and component NTSC video, HDMI, Digital Visual Interface (DVI), Video Graphics Array (VGA), Super Video Graphics Array (SVGA), and Super Extended Graphics Array (SXGA) computer graphics. All inputs and outputs shall allow for operator control in order to display any or all of this information on any number of display devices within the system. All inputs and outputs shall be sized with and without constrained proportions across multiple screens and moved at will around any display area and combination of displays.

The video display control system shall be expandable and scalable to support any combination of inputs and outputs. The video display control system with a minimum configuration of 4 composite video inputs, 4 component (RGB video inputs), and 4 HDMI inputs as well as network connections, decoders, and associated hardware and software required to display 32 inputs simultaneously at a minimum resolution of 720 pixels by 480 pixels and a frame rate of 30 fps, or as shown in the Plans. Provide the video display control system with a minimum configuration of 4 composite video outputs, 2 component (RGB video outputs), and 4 HDMI outputs. The video display control system can be expanded to accommodate at least 128 discreet inputs and outputs.

A single input shall be able to be routed to multiple displays simultaneously and multiple inputs can be routed to a single display simultaneously for viewing in separate windows. All inputs and outputs shall be synchronized by the video display control system and switching between inputs or outputs does not cause displayed images to unlock, roll, or otherwise exhibit visible distortion.

996-2.3.3.1 Analog Video: The video display control system shall be able to accept S-video, composite, and component video sources, and can digitize these signals for manipulation and display on any display device attached to the system. All analog video inputs shall use BNC connectors.

Analog video sources shall display within their own windows and can be resized up to or beyond their native resolution to conform to the wall display size.

996-2.3.3.2 Digital Video: The video display control system shall be able to accept digital video sources and can manipulate and display these signals on any display attached to the system. All digital video outputs shall use HDMI connectors unless otherwise directed.

Each MPEG video stream shall display within its own window and be freely movable and sizable up to or beyond its native resolution to conform to the wall display size.

996-2.3.3.3 RGB Video: Include an analog input that enables the TMC operator to project an exact copy of his or her workstation desktop display on the video wall display. Analog RGB inputs shall allow native images up to 1,280 pixels by 1,024 pixels at 60 Hz to be displayed on the video wall.

RGB inputs shall be sizable up to or beyond their native resolution to conform to the wall display size.

996-2.3.3.4 Streaming Media: The video display control system shall be able to display a minimum of 32 compressed video streams simultaneously in MPEG-2 over TCP/UDP/RTP over IP and supports multicasting as defined in Version 2 of the IGMP. The video display control system can display MPEG-4 and H.264. The MPEG video input interface is, at minimum, a 10/100 megabit per second network port per every 15 streams.

996-2.3.3.5 Primary Display Output: Video display control system can process the various signal input types to be viewed, such as the RGB feeds from monitor outputs and streaming video feeds. The unit shall provide direct digital streaming video through cable feeds using a digital video decoder. The video display control system shall provide the layout definitions for each signal to be displayed and save the predefined layouts and shall also permit switching of the predefined layouts and accept external alarm triggers to change the layouts.

The output capacity shall have sufficient memory and processing speed to provide fast rendering of video and image displays. The output has, at a minimum, a

dual HDMI connector that supports 1,280 horizontal pixels by 1,024 vertical pixels or greater resolution. The color depth is a minimum of 24 bits per pixel.

996-2.3.4 Electrical Requirements: Provide equipment that operates on 120 V_{AC} at a frequency of 60 Hz. Furnish a transformer or other necessary means of power conversion for any device that requires another voltage or frequency.

996-3 Network Devices.

996-3.1 General: Network devices shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

996-3.2 Managed Field Ethernet Switch:

996-3.2.1 Description: The Managed Field Ethernet Switch (MFES) shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216.

The MFES provides wire-speed fast Ethernet connectivity at transmission rates of 100 megabits per second.

Each MFES shall be managed individually and as a group for switch configuration, performance monitoring, and troubleshooting. The MFES shall include Layer 2+ capabilities, including, Quality of Service (QoS), IGMP, rate limiting, security filtering, and general management.

The MFES shall support half and full duplex Ethernet communications.

The MFES shall provide 99.999% error-free operation. The MFES shall comply with the EIA Ethernet data communication requirements using single-mode fiber optic transmission medium and Category 5E copper transmission medium.

The MFES shall have a minimum mean time between failures (MTBF) of 10 years, or 87,600 hours, as calculated using the Bellcore/Telcordia SR-332 standard for reliability prediction.

996-3.2.2 Networking Standards: The MFES shall comply with all applicable IEEE networking standards for Ethernet communications, including but not limited to:

1. IEEE 802.1Q standard for Local and Metropolitan Area Networks - Bridges and Bridged Networks used with port-based Virtual Local Area Networks (VLANs) and Rapid Spanning Tree Protocol (RSTP).
2. IEEE 802.1P standard for QoS.
3. IEEE 802.3 standard for LAN and Metropolitan Area Network (MAN) access and physical layer specifications.
4. IEEE 802.3u supplement standard regarding 100 Base TX/100 Base FX.
5. IEEE 802.3x standard regarding flow control with full duplex operation.

996-3.2.3 Optical Ports: All fiber optic link ports operate at 1,310 or 1,550 nanometers in single mode. All optical ports are Type ST, SC, LC, or FC only. Mechanical transfer registered jack (MTRJ) type connectors are not allowed.

MFES shall provide a minimum of two optical 100 Base FX ports capable of transmitting data at 100 megabits per second. MFES shall provide optical ports designed for use with a pair of fibers; one fiber will transmit (TX) data and one fiber will receive (RX) data. The optical ports shall have an optical power budget of at least 15 dB.

996-3.2.4 Copper Ports: MFES shall include a minimum of four copper ports. All copper ports shall be Type RJ-45 and shall auto-negotiate speed (i.e., 10/100 Base) and duplex (i.e., full or half). All 10/100 Base TX ports shall meet the specifications detailed in this section and shall be compliant with the IEEE 802.3 standard pinouts.

Ethernet over very high speed digital subscriber line (EoVDSL) ports shall support standard telephone-grade twisted copper pair and automatically negotiate the fastest data rate possible depending on cable length and quality.

996-3.2.5 Management Capability: The MFES shall support all Layer 2 management features and certain Layer 3 features related to multicast data transmission and routing. These features shall include, but not be limited to:

1. An MFES that is a port-based VLAN and supports VLAN tagging that meets or exceeds specifications as published in the IEEE 802.1Q standard and has a minimum 4-kilobit VLAN address table.
2. A forwarding/filtering rate that is a minimum of 14,880 packets per second for 10 megabits per second and 148,800 packets per second for 100 megabits per second.
3. A minimum 4 kilobit MAC address table.
4. Support of, at a minimum, IGMP Version 2.
5. Support of remote and local setup and management via secure shell (SSH) and secure Web-based GUI.
6. Support of the Simple Network Management Protocol (SNMP) version 1/2/3. Verify that the MFES can be accessed using the resident EIA-232 management port or a telecommunication network.
7. Support of Remote Authentication Dial-In User Service (RADIUS) or Terminal Access Controller Access-Control System Plus (TACACS+)
8. Support of remote monitoring (RMON) of the Ethernet agent and the ability to be upgraded to switch monitoring (SMON), if necessary.
9. Support of Secure Copy (SCP) or Secure File Transfer Protocol (SFTP) and either Network Time Protocol (NTP) or the Simple Network Time Protocol (SNTP). Ensure that the MFES supports port mirroring for troubleshooting purposes when combined with a network analyzer.

996-3.2.6 Mechanical Requirements: Every conductive contact surface or pin shall be gold-plated or made of a noncorrosive, nonrusting, conductive metal. Do not use self-tapping screws on the exterior of the assembly. All parts shall be made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-3.2.7 Electrical Requirements: The MFES shall operate on a nominal Voltage of 120 V_{AC}. Supply an appropriate voltage converter for devices that require operating voltages of less than 120 V_{AC}. The MFES shall have diagnostic Light Emitting Diodes (LEDs), including link, TX, RX, and power LEDs.

996-3.2.8 Environmental Requirements: MFES shall operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 2 2021, Sections 2.2.7, 2.2.8., and 2.2.9.

996-3.3 Managed Hub Ethernet Switch:

996-3.3.1 Description: The Managed Hub Ethernet Switch (MHES) shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment https://www.ecfr.gov/current/title-2/subtitle-A/chapter-II/part-200/subpart-C/section-200.216.

The MHES shall provide Ethernet connectivity at transmission rates of 10/100/1000/10000 megabits per second. The MHES shall support half and full duplex Ethernet communications. The MHES must support 12000 IPv4 routes and 2000 IPv6 routes and all routing protocols shall be in performed hardware to ensure maximum speed.

The MHES shall support management individually and as a group for switch configuration, performance monitoring, and troubleshooting. The MHES shall include Layer 2 capabilities, including, QoS, IGMP, rate limiting, security filtering, and general management.

The MHES shall include full Layer 3 capabilities, including Open Shortest Path First (OSPF) routing protocol, Routing Information Protocol (RIP), and Protocol Independent Multicasting (PIM). The MHES includes all license(s) required to utilize all Layer 3 features.

996-3.3.2 Networking Standards: The MHES shall comply with all applicable IEEE networking standards for Ethernet communications, including:

1. IEEE 802.1Q Standard for Local and Metropolitan Area Networks - Bridges and Bridged Networks used with port-based Virtual Local Area Networks (VLANs) and Rapid Spanning Tree Protocol (RSTP).
2. IEEE 802.1P standard for QoS.
3. IEEE 802.3 standard for Local Area Network (LAN) and metropolitan area network (MAN) access and physical layer specifications.
4. IEEE 802.3u supplement standard regarding 100 Base TX/100 Base FX.
5. IEEE 802.3x standard regarding flow control with full duplex operation.
6. IEEE 802.3z supplement standard regarding 1000 Base X.

996-3.3.3 Optical Ports: All fiber optic link ports operate at 1,310 or 1,550 nanometers in single mode. Provide Type LC connectors unless otherwise directed. Mechanical transfer registered jack (MTRJ) type connectors are not allowed.

MHES shall provide a minimum of 6 optical ports capable of transmitting data at 10/100/1000/10000 megabits per second. MHES shall provide optical ports designed for use with a pair of fibers; one fiber will transmit (TX) data and one fiber will receive (RX) data. The optical ports shall have an optical power budget of at least 15 dB.

996-3.3.4 Copper Ports: MHES shall include a minimum of 12 10/100/1000 Base TX copper ports. All copper ports shall be Type RJ-45 and shall auto-negotiate speed (i.e., 10/100/1000 Base) and duplex (i.e., full or half). All 10/100/1000 Base TX ports shall meet the specifications detailed in this section and shall be compliant with the IEEE 802.3 standard pinouts.

996-3.3.5 Management Capability: MHES shall support all Layer 2 management features and all Layer 3 features as defined by this Section. Layer 2 and Layer 3 features must include:

1. Port-based VLAN and VLAN tagging that meets or exceeds specifications as published in the IEEE 802.1Q standard and has a minimum 4-kilobit VLAN address table.
2. A forwarding/filtering rate that is a minimum of 14,880 packets per second for 10 megabits per second, 148,800 packets per second for 100 megabits per second, and 1,488,000 packets per second for 1000 megabits per second.
3. A minimum 4 kilobit MAC address table.

4. Support of IGMP Version 2.

5. Support of remote and local setup and management via secure shell and secure Web-based GUI.

6. Support of the Simple Network Management Protocol (SNMP) version 2 and version 3.

7. Support of Remote Authentication Dial-In User Service (RADIUS) or Terminal Access Controller Access-Control System Plus (TACACS+).

8. Support of remote monitoring (RMON) of the Ethernet agent and the ability to be upgraded to switch monitoring (SMON), if necessary.

9. Support of SCP or SFTP and either Network Time Protocol (NTP) or the Simple Network Time Protocol (SNTP). Ensure that the MHES supports port mirroring for troubleshooting purposes when combined with a network analyzer.

10. Sampled Flow Network Monitoring export protocol capable of being turned on or off on individual Ethernet ports without affecting traffic.

12. OSPF routing protocol. 12000 IPv4 routes and 2000 IPv6 routes.

12. RIP.

13. Virtual Router Redundancy Protocol (VRRP).

996-3.3.6 Mechanical Specifications. Ensure the MHES is no greater than 1-Rack Unit tall.

Every conductive contact surface or pin shall be gold-plated or made of a noncorrosive, nonrusting, conductive metal. Do not use self-tapping screws on the exterior of the assembly. All parts shall be made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-3.3.7 Electrical Specifications. MHES must shall operate on a nominal voltage of 120 V_{AC}. Supply an appropriate voltage converter for devices that require operating voltages of less than 120 V_{AC}. The MHES shall have diagnostic LEDs, including link, TX, RX, and power LEDs.

996-3.3.8 Environmental Specifications. Ensure that the MHES has an operating temperature range of -34° Celsius to 74° Celsius. Ensure that the MHES can withstand 90 percent non-condensing relative humidity at 40° Celsius.

996-3.4 Device Server:

996-3.4.1 Description: The device server allows the connection of serial devices with EIA-232, EIA-422, and EIA-485 connections to an Ethernet network. The device server provides a TCP/IP interface to one or more field devices using EIA-232/422/485 standard connections. The device server supports TCP/IP, UDP/IP, Dynamic Host Configuration Protocol (DHCP), Address Resolution Protocol (ARP), Internet Control Message Protocol (ICMP), Simple Network Management Protocol (SNMP), Hypertext Transfer Protocol (HTTP), and telnet.

The device server shall provide 99.999% error-free operation and EIA-compatible Ethernet data communication by way of a Category 5E copper or fiber optic transmission medium.

The device server is resistant to all electromagnetic interference.

Data security shall comply with Version 2 of the Secure Shell Protocol (SSHv2), or the NIST requirements as defined in the Federal Information Processing Standard (FIPS) Publication (PUB)-197 for the Advanced Encryption Standard (AES).

The device server has a minimum mean time between failures (MTBF) of 10 years, or 87,600 hours.

996-3.4.2 Serial Interface: The device server provides a minimum of one serial data interface and connector that conforms to EIA-232/422/485 standards. The serial interface supports 2-wire and 4-wire EIA-485 connections. The serial ports support data rates up to 230 kbps; error detection procedures utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

The device server provides flow control (request to send [RTS]/clear to send [CTS] and transmit on/transmit off [XON/XOFF]), as well as allow control of the Data Terminal Ready (DTR), Data Carrier Detect (DCD), Data Set Ready (DSR), CTS, and RTS signals. The device server supports RTS toggle for half-duplex emulation.

996-3.4.3 Network Interface: The device server includes a minimum of one Ethernet port, which shall provide a 10/100 Base TX or a 10/100 Base FX connection as specified in the Plans. All copper-based network interface ports utilize registered jack (RJ)-45 connectors. The optical ports are Type ST, SC, LC, or FC only. Mechanical transfer registered jack (MTRJ) type connectors are not allowed.

996-3.4.4 Configuration and Management: The device server shall support local and remote configuration and management, which shall include access to all user-programmable features, including but not limited to addressing, port configuration, device monitoring, diagnostic utilities, and security functions. The device server shall support configuration and management via SNMP, telnet login, and browser-based interface.

996-3.4.5 Mechanical Requirements: Do not use self-tapping screws on the exterior of the assembly. All parts are made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-3.4.6 Electrical Requirements: The device server operates using a nominal input voltage of 120 V_{AC} If the device requires nominal input voltage of less than 120 V_{AC}, furnish the appropriate voltage converter. The maximum power consumption shall not exceed 12 watts. The device server has diagnostic LEDs, including link, TX, RX, and power LEDs.

996-3.4.7 Environmental Requirements: The device server performs all required functions during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

996-3.5 Digital Video Encoder and Decoder:

996-3.5.1 Description: The Digital Video Encoder (DVE) and Digital Video Decoder (DVD) are specialized network-based hardware devices and software which allow video and data signals to be transmitted across IP networks. The video and data packets produced by the DVE and placed onto the network allow reconstruction of digital video signals by hardware-based and software-based DVDs that are also attached to the network.

996-3.5.2 Software: All setup, control programs, and diagnostic software related to the DVE or DVD shall be provided. All equipment licenses, where required for any software or hardware in the system, shall be provided.

996-3.5.3 MPEG-2 Format: DVE and DVD components utilize the Moving Picture Experts Group's MPEG-2 video compression technology in accordance with the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) requirements detailed in the ISO/IEC 13818 standard. The DVE and DVD are capable of unicast and multicast operation. DVEs support the Session Announcement Protocol (SAP) as recommended by the Internet Engineering Task Force (IETF) RFC 2974. The

DVE provides 99.999% error-free operation. The MPEG-2 DVE and DVD equipment support programmable bit rates. MPEG-2 equipment supports fixed bit rate mode.

996-3.5.4 H.264 Format: DVE and DVD components utilize the video compression technology in accordance with the International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) requirements detailed in the ISO/IEC 14496-10:2009 standard. The DVE and DVD are capable of unicast and multicast operation. DVEs shall support the Session Announcement Protocol (SAP) as recommended by the Internet Engineering Task Force (IETF) RFC 2974, and Real Time Streaming Protocol (RTSP). The DVE provides 99.999% error-free operation. H.264 DVE and DVD equipment support programmable bit rates. H.264 equipment supports fixed bit rate mode.

996-3.5.5 Digital Video Encoder: The DVE is a hardware-based network device that is able to accept a minimum of one analog NTSC video input and digitize it for transport across IP networks. The DVE provides a minimum of one serial data interface for transmission of command and control data to other devices (typically camera PTZ commands), as well as console and configuration functions. Provide compatible decoder software along with the DVE.

996-3.5.6 Hardware-based Decoder: The hardware-based DVD has a minimum of one video output. The DVD that has a minimum of one data interface for configuration functions. The DVD includes an Ethernet interface for connection to IP networks.

996-3.5.7 Interoperability: The DVE is compatible and fully interoperable with software and hardware DVDs from the DVE manufacturer, as well as a minimum of two software and hardware DVDs from other manufacturers. The DVD is compatible and fully interoperable with DVEs from the DVD manufacturer, as well as a minimum of two other DVEs from other manufacturers. The DVE and DVD can be controlled using SunGuide® or support stream selection and switching using ONVIF commands.

996-3.5.8 Video Requirements: Composite video inputs and outputs utilize BNC connectors. Analog video inputs and outputs support 1 volt peak-to-peak (Vp-p) NTSC composite video. The DVE and DVD operate with both color and monochrome video, and DVEs allow the user to select and adjust video resolution. The DVE and DVD support resolutions that include, but are not limited to, those defined in Table 996-2. The DVE and DVD are capable of delivering color and monochrome video at 30 fps regardless of resolution.

Table 996-2
Resolution Requirements

Format	Resolutions
MPEG-2	352 x 240, 352 x 480, 720 x 480
H.264	176 x 120, 352 x 240, 720 x 480

Note: The resolutions attained depend on the data transmission rate.

996-3.5.9 Serial Interface: Hardware-based DVEs provide a minimum of one serial data interface that support EIA/TIA-232 and TIA-422. The serial ports support data rates up to 115 kbps; error detection procedures utilizing parity bits (i.e., none, even, and odd); and stop bits (1 or 2).

Hardware-based DVEs provide a TCP/IP interface to their serial port using a network socket connection with configurable IP address and port number. Serial interface ports may utilize RJ-45 connectors, D-sub connectors, or screw terminals.

996-3.5.10 Network Interface: The DVE/DVD LAN connection supports the requirements detailed in the IEEE 802.3 standard for 10/100 Ethernet connections. The DVE/DVD has a minimum of one Ethernet port, which shall be a 10/100 Base TX connection or a 100 Base FX ST, SC, LC or FC interface. The connector complies with applicable EIA and TIA requirements. Copper-based network interface ports shall utilize RJ-45 connectors. Fiber ports are single mode with a minimum link budget of 30 dB.

The network communication conforms to UDP, Version 4 of the Internet Protocol (IP) and IGMP Version 2.

996-3.5.11 Front Panel Status Indicators: DVEs and DVDs have LED displays, Liquid Crystal Displays (LCDs), or similar illuminated displays to indicate status for power and data activity.

996-3.5.12 Configuration and Management: DVEs and DVDs shall support local and remote configuration and management. Configuration and management functions shall include access to all user-programmable features, including but not limited to addressing, serial port configuration, video settings, device monitoring, and security functions. DVE and DVD support configuration and management via serial login, telnet login, web browser, or Simple Network Management Protocol (SNMP).

996-3.5.13 Mechanical Requirements: Do not use self-tapping screws on the exterior of the assembly. All equipment uses parts made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-3.5.14 Electrical Requirements: All equipment operates on a nominal voltage of 120 V_{AC}. If the device requires operating voltages of less than 120 V_{AC}, supply the appropriate voltage converter.

996-3.5.15 Environmental Requirements: DVEs and DVDs installed in roadside cabinets shall perform all required functions during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9. Hardware DVD installed in a climate-controlled environment, such as a TMC computer room, has an operating temperature range of 32 to 104°F.

996-3.6 Media Converter:

996-3.6.1 Description: The media converter connects different transmission media for the purposes of transmitting Ethernet data.

996-3.6.2 Network Interface: The media converter LAN connection supports the requirements detailed in the IEEE 802.3 standard for 10/100 Ethernet connections. The media converter has a minimum of one Ethernet port, which shall be, at a minimum, a 10/100 Base TX connection or a 100 Base FX ST, SC, LC or FC interface. The connector complies with applicable EIA and TIA requirements. Copper-based network interface ports utilize RJ-45 connectors. Fiber ports are single mode with a minimum link budget of 30 dB.

996-3.6.3 Mechanical Requirements: Every conductive contact surface or pin shall be gold-plated or made of a noncorrosive, nonrusting, conductive metal. Do not use self-tapping screws on the exterior of the assembly. All parts shall be made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-3.6.4 Electrical Requirements: Ethernet to coax media converters shall operate using Power Over Ethernet (POE). Media converters shall operate on a nominal voltage of 120 V_{AC} if POE is unavailable. Supply an appropriate voltage converter for devices that require operating voltages of less than 120 V_{AC}. Ensure that the media converter has diagnostic LEDs, including link, TX, RX, and power LEDs.

996-3.6.5 Environmental Requirements: Ensure media converters perform all required functions during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

996-4 Grounding and Lightning Protection.

996-4.1 General: Surge Protective Devices for traffic control devices, including intelligent transportation system (ITS), shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

996-4.2 Surge Protective Device:

996-4.2.1 Description: Surge Protective Devices (SPDs) protect electronics from lightning, transient voltage surges, and induced current.

996-4.2.2 SPD for 120 Volt or 120/240 Volt Power: The SPD shall include L-N, L-G, and N-G protection and have a maximum surge current rating of 50 kA per phase or greater. The SPD shall meet the requirements of UL 1449, Third Edition and be listed by a NRTL.

The SPD shall have a visual indication system that monitors the weakest link in each mode and shows normal operation or failure status and also provides one set of normally open (NO)/normally closed (NC) Form C contacts for remote alarm monitoring. The enclosure for a SPD shall have a NEMA 4 rating.

996-4.2.3 SPD at Point of Use: The SPD shall comply with the minimum functional requirements shown in Table 996-3. The units shall be rated at 15 or 20 amps load and are configured with receptacles.

The units shall have internal fuse protection and provide common mode (L+N-G) protection.

996-4.2.4 SPD for Low-Voltage Power, Control, Data and Signal Systems: The SPD devices shall comply with the minimum functional requirements shown in Table 996-3 for all available modes (i.e., power L-N, N-G; L-G, data and signal center pin-to-shield, L-L, L-G, and shield-G where appropriate).

Table 996-3

SPD Minimum Requirements

Circuit Description	Clamping Voltage	Data Rate	Surge Capacity	Maximum Let-Through Voltage
12 V_{DC}	15-20 volts	N/A	5kA per mode (8x20 µs)	<150 Vpk
24 V_{AC}	30-55 volts	N/A	5kA per mode (8x20 µs)	<175 Vpk
48 V_{DC}	60-85 volts	N/A	5kA per mode (8x20 µs)	<200 Vpk
120 V_{AC} at POU	150-200 volts	N/A	20kA per mode (8x20 µs)	<550 Vpk

Table 996-3				
SPD Minimum Requirements				
Circuit Description	Clamping Voltage	Data Rate	Surge Capacity	Maximum Let-Through Voltage
Coaxial Composite Video	4-8 volts	N/A	10kA per mode (8x20 µs)	<65 Vpk (8x20 µs/1.2x50µs; 6kV, 3kA)
RS422/RS485	8-15 volts	10 Mbps	10kA per mode (8x20 µs)	<30 Vpk
T1	13-30 volts	10 Mbps	10kA per mode (8x20 µs)	<30 Vpk
Ethernet Data	7-12 volts	1 Gbps	1kA per mode (10x1000 µs)	<30 Vpk
PoE	60-70 volts	1 Gbps	5kA per mode (8x20 µs)	<200Vpk (100kHz 0.5µs; 6kV, 500A)
PoE+, PoE++	<150	1 Gbps	1kA L-G (8x20 µs)	<350V

SPDs for PoE, PoE+, and PoE++ applications shall meet IEEE 8802-3.

The SPDs shall meet the requirements of UL 497B or UL 497C, as applicable, and are listed by a NRTL.

996-4.2.5 Mechanical Specifications: All parts shall be made of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal.

996-4.2.6 Environmental Specifications: The SPDs shall operate properly during and after being subjected to the temperature and humidity test described in NEMA TS 2-2021, Section 2.2.7, and the vibration and shock tests described in NEMA TS 2-2021, Sections 2.2.8 and 2.2.9.

996-5 Pull and Splice Boxes.

996-5.1 General: Pull and splice boxes shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

The box bodies and covers shall be free of flaws such as cracks, sharp, broken, or uneven edges, and voids.

Ensure in-ground boxes have an open bottom design.

996-5.2 Marking: The following information shall be permanently cast or engraved into the top surface of all pull and splice box covers. If used, identification plates shall be UV stable, mechanically fastened, bonded with adhesive material suitable for outdoor applications, and capable of installation in the field

1. Mark application as follows:

FDOT TRAFFIC SIGNAL for signalized intersections
FDOT FIBER OPTIC CABLE for fiber optic cable
FDOT LIGHTING for highway lighting
FDOT TRAFFIC MONITORING for traffic monitoring

2. Manufacturer's name or logo
3. FDOT APL approval number
4. TIER rating

The date of manufacture (month/day/year, or date code) shall be permanently located on the top or bottom of the cover. The interior of the box body shall have a permanent marking that includes the manufacturer part/model number and date of manufacture near the top of box in a location that is visible after installation when the cover is removed.

996-5.3 Dimensions: For signalized intersection and lighting applications, pull boxes with nominal cover dimensions of 13 inches wide by 24 inches long or larger and no less than 12 inches deep shall be provided. The inside opening area shall be a minimum of 240 square inches and no inside dimension shall be less than 12 inches.

For fiber optic cable applications, pull boxes with nominal cover dimensions of 24 inches wide by 36 inches long or larger and no less than 24 inches deep shall be provided.

Rectangular splice boxes with nominal cover dimensions of 30 inches wide by 60 inches long or larger and no less than 36 inches deep shall be provided. Round splice boxes with a nominal cover diameter of 36 inches or larger and no less than 36 inches deep shall be provided.

996-5.4 Fabrication: Box covers shall be constructed of concrete, polymer concrete or other materials meeting the requirements of this Section.

Box covers with lifting slots and a flush-seating lockdown mechanism shall be provided. Penta-head or other non-standard, security type lockdown lag bolts shall be used. Lockdown bolts and lifting slots shall be Type 316, 304, or 302 passivated stainless steel or brass. Lockdown bolt assembly shall be designed to prevent seizing and can be removed without damaging the cover or box body. The lockdown bolt threaded insert/nut assembly shall be field replaceable.

996-5.5 Testing Requirements: Pull and splice boxes shall meet or exceed the American National Standards Institute/Society of Cable Telecommunications Engineers (ANSI/SCTE) 77 2017 Specification for Underground Enclosure Integrity for TIER 15 loading requirements with the following additional clarifications and requirements:

1. Apply all environmental tests to the box and its cover.
2. All flexural testing shall be conducted in accordance with an appropriate ASTM standard and clearly stated in the report.
3. Perform repetitions of Cycle 1 in Table X2.1 of ASTM G154 for a minimum duration of 1000 hours for the simulated sunlight exposure test.
4. Use deflection-measuring devices positioned to measure vertical and lateral deflection (wherever maximum deflection occurs) for the vertical sidewall load test.
5. Conduct the lateral sidewall pressure, vertical sidewall load and cover vertical load tests without any removable or permanent wall to wall supporting beams located in the interior or top of the box opening.

When testing pull and splice boxes of various sizes (width x length x depth), the cover impact test, internal equipment protection test, coefficient of friction test, and all environmental tests, can be completed using a single representative box/cover (instead of samples from all box/cover sizes) as long as the test report indicates the following:

1. Materials of construction, compositions, and manufacturing processes are identical for all box and cover sizes submitted for listing on the APL.

2. Size (width x length x depth) of the representative box/cover.

996-6 Camera Lowering Device.

996-6.1 General: Camera lowering devices shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

The lowering device shall provide the electrical connection between the control cabinet and the equipment installed on the lowering device without reducing the function or effectiveness of the equipment. The lowering device system support arm shall be capable of withstanding service tension and shear up to 1 kip minimum.

The lowering device shall include a disconnect unit and power, data, and video cables (as applicable) for connecting equipment, a divided support arm, pole attachment provisions, a rotatable pole-top tenon, and a pole-top junction box.

All external components shall be made of corrosion-resistant materials that are powder-coated, galvanized, or otherwise protected from the environment. All finished castings shall have a smooth finish free from cracks, blow-holes, shrinks, and other flaws. All roller fairlead frames shall be corrosion resistant stainless steel or aluminum. All pulleys used in the lowering device and portable lowering tool shall have sealed, self-lubricated or oil-tight bearings, or sintered bronze bushings.

A minimum of 100 feet of composite power and signal cable prewired to the lowering device at the factory shall be provided. Splices will not be allowed.

Lowering devices shall be designed to withstand the design wind speeds defined in the Department's Structures Manual.

996-6.2 Equipment Connection Box: A 1-1/2 inch National Pipe Thread (NPT) pipe connection point and pipe for attaching a camera shall be included. The pipe between the connection box and camera shall be aluminum. The equipment connection box shall have an ingress protection rating of no less than IP55.

996-6.3 Disconnect Unit: The disconnect units shall have a minimum load capacity of 600 pounds with a 4:1 safety factor and be capable of securely holding the lowering device and any installed equipment. Fixed and movable components of the disconnect unit shall have a locking mechanism between them, with at least two mechanical latches for the movable assembly. The fixed unit shall have a heavy-duty cast tracking guide that allows latching in the same position each time. The load shall be transferred from the lowering cable to the mechanical latches when the system is in the latched position. Interface and locking components shall be constructed of stainless steel or aluminum.

996-6.3.1 Disconnect Unit Housing: The disconnect unit housing shall be weather-proof with an ingress protection rating of no less than IP55.

996-6.3.2 Connector Block: Modular, self-aligning and self-adjusting female and male socket contact halves in the connector block shall be provided. Equip the lowering device with enough contacts to permit operation of all required functions of the camera, up to a maximum of 20 contacts and include at least two spare contacts. Contact connections between the fixed and movable lowering device components that are capable of passing EIA-232, EIA-422, EIA-485, and Ethernet data signals and 1 volt peak to peak (Vp-p) video signals, as well as 120 V_{AC}, 9-24 V_{AC}, and 9-48 V_{DC} power shall be provided. The lowering device connections shall be capable of carrying the signals, voltages, and current required by the devices connected to them under full load conditions.

Only corrosion-resistant stainless steel hardware shall be used. male contacts used for grounding shall mate first and break last. All contacts and connectors shall be self-aligning and self-adjusting mechanical systems. A spring-assisted contact assembly to maintain constant pressure on the contacts when the device is in the latched position shall be provided.

Connector pins made of brass- or gold-plated nickel, or gold-plated copper shall be provided.

Current-carrying male and female contacts shall be a minimum of 0.09 inch in diameter and firmly affixed to the connector block. Ensure mated connectors do not allow water penetration.

996-6.4 Lowering Tool: A portable metal-frame lowering tool manufactured of corrosion-resistant materials with winch assembly and a cable with a combined weight less than 35 lbs that is capable of securely supporting itself and the load shall be provided. The lowering tool shall include a quick release cable connector, and a torque limiter that will prevent over-tensioning of the lowering cable and be equipped with gearing that reduces the manual effort required to operate the lifting handle to raise and lower a capacity load. Ensure that the lowering tool can be powered using a 1/2-inch chuck, variable-speed reversible industrial-duty electric drill capable of matching the manufacturer-recommended revolutions per minute. An adapter with a clutch mechanism and torque limiter for use with the drill shall be provided.

The winch assembly shall have a minimum drum size width of 3.75 inches and a positive braking mechanism to secure the cable reel during raising and lowering operations, and to prevent freewheeling. The lowering cable shall wind evenly on the winch drum during operation. Provide a manual winch handle that incorporates a non-shear pin type torque limiter that can be used repeatedly and will not damage the lowering system.

Provide a minimum of one lowering tool and any additional tools required to operate the lowering device.

996-6.5 Lowering Cable: The lowering cable shall be 0.125-inch minimum diameter Type 316 stainless steel aircraft cable (7 strands x 19 gauge) with a minimum breaking strength of 1,760 pounds. Additionally, the lowering cable assembly (as installed with thimble and crimps on one end and a cable clamp inside the latch on the lowering device end), shall have a minimum breaking strength of 1,760 lbs.

All lowering cable accessories, such as connecting links, shall have a minimum workload rating that meets or exceeds that of the lowering cable.

Prefabricated components for the lift unit support system shall prevent the lifting cable from contacting the power or video cables.

996-6.6 Wiring: All wiring must meet NEC requirements.

996-6.7 External-Mount Lowering System Enclosure for Mounting to Existing Structures: The system shall include an upper mounting/junction box, winch assembly and all external conduit and cabling necessary for mounting to existing structures.

A NEMA 4 rated lower lockable pole-mounted cabinet, constructed of corrosion-resistant 5052 sheet aluminum with a minimum thickness of 1/8 inch, to house the winch assembly shall be provided. The cabinet shall allow for unobstructed operation of the winch, access for servicing and provide sufficient clear area for operation of the winch manually and with an electric drill. The outside surface of the cabinet shall have a smooth, uniform natural aluminum finish. All inside and outside edges of the winch cabinet shall be free of burrs, and all welds must be neatly formed, free of cracks, blow holes, and other irregularities. Cabinet hinges

shall be vandal-resistant and constructed of 14 gauge stainless steel or 1/8 inch aluminum with stainless steel hinge pins.

The cabinet door shall be double-flanged and include neoprene closed-cell gaskets permanently secured on the interior door surfaces that contact the door opening. The cabinet door shall not sag. Include a pin tumbler lock keyed for use with a No. 2 key and two keys. The cabinet door handle shall include a lock hasp that will accommodate a padlock with a 7/16-inch diameter shackle.

The upper mounting/junction box shall include a maintenance access door with captive attachment hardware. All necessary mounting hardware, conduits, standoffs, and conduit mounts required for a complete and functional system shall be provided.

The external conduit shall be galvanized Schedule 40 with National Pipe Thread Taper (NPT) threads and have a minimum ID of 3 inches at the lower winch cabinet entrance and allow the lowering cable to wind evenly on the winch drum without binding. All conduit couplings and connections between the pole-mounted cabinet and upper mounting/junction box shall be watertight.

996-7 Traffic Control System Auxiliaries.

996-7.1 General: Traffic Control System Auxiliaries shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product shall submit an application in accordance with Section 6.

996-7.2 Uninterruptible Power Supply (UPS): The UPS shall be either a line interactive or online/double-conversion UPS. UPS assemblies shall be designed for installation in a roadside NEMA 3R enclosure to provide battery backup functionality for traffic control systems, including traffic signal and intelligent transportation system (ITS) devices. UPS assemblies shall include batteries provided by the UPS manufacturer or in accordance with manufacturer's requirements.

Loss of utility power, transfer from utility power to battery power, and transfer back to utility power shall not interfere with normal operation of connected equipment. In the event of UPS failure or battery depletion, connected equipment shall be energized automatically upon restoration of utility power.

The UPS shall operate in hot standby mode with power transfer being accomplished in 40 milliseconds or less.

Removal and replacement of the UPS shall not disrupt the operation of the equipment being protected.

All harnesses necessary to connect and operate the system shall be included. All connectors shall be keyed to prevent improper connection.

996-7.2.1 Configuration and Management: The UPS shall support local and remote configuration and management, including access to all user-programmable features as well as alarm monitoring, event logging, and diagnostic utilities.

Configuration and management functions shall be password protected.

Alarm function monitoring shall include the following: loss of utility power, inverter failure, low battery, voltage, and temperature out of range. The UPS shall include an event log that indicates the date and time of the following events: AC high, AC low, AC frequency error, AC fail/blackout, and over temperature. The UPS event log shall be able to store a minimum of 60 events.

The UPS shall include a front panel display and controls that allows programming of configurable parameters, features, and functions without the need for another

input device. The UPS shall have visual indications for Power-On, Mode of Operation (utility power or inverter), Battery Status, Alarm Status, Load Levels, and AC Output Voltage.

996-7.2.2 Communication Interfaces: The UPS shall include an Ethernet port (RJ45) for local control using a laptop PC and remote control via a network connection.

996-7.2.3 Batteries: Batteries must be provided by the UPS manufacturer or in accordance with manufacturer's recommendations. Batteries shall be sealed and require no maintenance, cause no corrosion, and be capable of maintaining 80% of original capacity and performance for a minimum of five years.

The UPS shall be supplied with a wiring harness for battery connections. The battery wiring harness shall allow 6 feet of separation between the UPS and its battery bank. Battery terminals shall include a protective covering to prevent accidental spark or shorting.

The UPS shall include battery management functions that includes active or equalized balancing; monitoring of temperature, voltage, and amperage of charge and discharge; and temperature compensated automatic charging to maximize the life of the batteries.

996-7.2.4 Electrical: UPS assemblies used to provide backup power in an ITS cabinet shall provide a minimum of 350 watts (at 120 V_{AC}) of continuous backup power for a minimum of two hours.

UPS assemblies used to provide backup power in a traffic signal controller cabinet shall provide a minimum 400 watts (at 120 V_{AC}) of continuous power for a minimum of 6.5 hours.

Frequency shall be regulated to 60 Hz, plus or minus 0.5 Hz, while the UPS is supplying power. The UPS shall operate on 85 to 140 V_{AC} without requiring assistance from the batteries.

The UPS shall be listed to the requirements of UL 1778. Upstream back feed voltage from the UPS shall be less than 1 $V_{AC.}$

Double-conversion UPS shall be capable of simultaneously producing fully regenerated and regulated, conditioned, True Sine Wave power and hot standby AC output, and have a minimum operating efficiency of 90%.

996-7.2.5 Traffic Signal UPS Cabinet: Cabinets used to house traffic signal UPS assemblies shall be designed to be mounted to the side of a traffic cabinet or base mounted. Cabinets shall meet the requirements of Section 676 and include shelves and rack rails to house all UPS system components including the UPS, batteries, harnesses, switches, surge protective device, power terminal block and a generator hookup with transfer switch. The UPS cabinet shall allow a maintenance technician to safely insert power for traffic signal operation while the UPS or associated equipment is serviced or replaced.

A surge protective device shall be installed where the supply circuit enters the cabinet in accordance with Section 620-2.

The cabinet shall include a 20 A, 120 volt, 60 Hz GFCI receptacle. The receptacle shall be wired to utility power and not regulated by the UPS module. The cabinet shall include a main breaker and a breaker for the technician GFCI outlet.

996-7.2.5.1 Transfer Switch and Generator Access Panel: The cabinet shall include an automatic transfer switch and generator access panel in accordance with Section 676. The generator access door shall not protrude more than 1 inch when closed.

996-7.2.6 Mechanical: All parts shall be made of corrosion-resistant materials such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements shall be Type 304 or 316 passivated stainless steel.

996-7.2.7 Environmental: UPS assemblies, including batteries, shall provide continuous power with specified wattage and operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

996-7.3 Remote Power Management Unit (RPMU): The RPMU shall be designed for installation in a roadside Traffic Cabinet to provide remote control of electrical receptacles.

996-7.3.1 Configuration and Management: Provide a RPMU that supports local and remote configuration and management, including access to all user-programmable features as well as alarm monitoring, event logging, and diagnostic utilities.

Configuration and management functions shall be password protected.

The RPMU shall include an event scheduler that can store a minimum of 60 events.

The RPMU shall include LED indicators for relay inputs and outlet status.

Upon loss of communications the RPMU shall maintain each receptacle and relay in its currently stored state of operation.

Upon restoration of electrical power after an outage the RPMU shall automatically restore each receptacle and relay to its previously stored state of operation and all configurable parameters shall be retained.

The unit shall support SNMP v2c, including trap notifications of receptacle state changes.

996-7.3.2 Communication Interfaces: The RPMU shall have an Ethernet port (RJ45) for local control using a laptop PC and remote control via a network connection.

996-7.3.3 Electrical: The RPMU shall have a minimum of 6 NEMA 5-15R receptacles, nominal 120 V_{AC}. The RPMU shall have a minimum current capacity of 12 amperes (amps).

996-7.3.4 Mechanical: All parts shall be made of corrosion-resistant materials such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements shall be Type 304 or 316 passivated stainless steel.

996-7.3.5 Environmental: The RPMU shall operate properly during and after being subjected to the environmental testing procedures described in NEMA TS 2-2021, Sections 2.2.7, 2.2.8, and 2.2.9.

SECTION 997
TRAFFIC MONITORING SITE MATERIALS

997-1 Description.

This Section governs the requirements for all traffic monitoring site (TMS) material as shown in the Plans and Standard Plans.

Provide products compatible with all other TMS APL equipment. Any electronics unit or software submitted for approval must be compatible with or convert the data into a format compatible with the Department's polling and processing software. Any substitute software modules submitted must be tested and approved by the Department.

Provide products constructed of corrosion-resistant materials, such as plastic, stainless steel, anodized aluminum, brass, or gold-plated metal. All fasteners exposed to the elements shall be Type 304 or 316 passivated stainless steel.

Provide warranties that are fully transferrable to the Department. Terms and conditions of warranties must be documented when submitting a request to the Department for certification. Include terms for a specified service performance with provisions for repair parts and labor, or for replacement.

Ensure the terms and conditions define the equipment installation date as the date for such warranty to be in effect. The installation date for construction projects is the day the site is accepted by the Engineer. For warehouse purchases, the installation date is the date of visual inspection approval, not to exceed ten days after delivery date.

Furnish replacements within 10 calendar days of notification for any part or equipment found to be defective during the warranty period at no cost to the Department.

997-1.1 Approved Product List Submittal Requirements: All products shall be listed on the Department's Approved Product List (APL). Manufacturers seeking evaluation of their product for inclusion on the APL shall submit an application in accordance with Section 6 including documentation identified in Table 997-1 and this section. Documentation must demonstrate that the product meets the requirements of this Section.

Table 997-1

Documentation	Requirements
Technical Data Sheets	This document will be used to verify physical and performance properties.
Product Label Photo	Provide equipment permanently marked with manufacturer name or trademark, part number, and date of manufacture or serial number.
Product Sample	When requested, submit a product sample.
Installation Manual	Instructions describing mounting, cabling, and configuration.
Product Photo	Display significant features of the products.

997-2 TMS Vehicle Sensors (Non-Weight).

997-2.1 General: Non-weight vehicle sensors include inductive loops, Class II piezoelectric axle sensors, microwave radar, and video data collection technologies.

997-2.2 Wire for Inductive Loops: Materials used in the creation of the inductive loops must meet the material specification of No. 14 AWG International Municipal Signal Association (IMSA) 51-7 wire.

997-2.3 Class II Piezoelectric Axle Sensor: In-Roadway Class II piezoelectric axle sensors shall meet the physical characteristics in Table 997-2.

Table 997-2 Physical Characteristics, Class II Piezoelectric Axle Sensor	
Property	Requirements
Sensor Element Dimensions	Approximately 6 ft. to 10 ft. in length, 3/16 in. to 3/8 in. in diameter (varies by manufacturer)
Sensor Element Material	Pressure sensing piezoelectric
Pavement Operating Temperature Range	Minimum 0°F to +150°F
Output Signal	Minimum +200mV or produce a charge signal for a FHWA Class 2 Vehicle.
Environmental Requirements	NEMA TS-2, Section 2

997-2.4 Microwave Radar Sensor: Sensors shall meet the physical characteristics in Table 997-3.

Table 997-3 Physical Characteristics, Microwave Radar Sensor	
Property	Requirement
Detection Range	A minimum of 8 distinguishable lanes within a minimum 200 feet of detection zone.
Direction	Bidirectional
Operating Temperature Range	Ambient temperature of 0°F to 140°F
Enclosure Dimensions	Weatherproof aluminum, stainless steel, or polycarbonate housing. Typically, up to 15” X 12” X 6” Weight typically <10 lbs.
Operating Frequency	Wireless transmission in Federal Communications Commission (FCC) approved band or unlicensed RF range.
Communications	RS-232/RS-485 ports, supports minimum 19,200 baud rate.
Data Interface Compatibility	Compatible with the vehicle speed/classification unit and the Department’s traffic polling system.

997-2.5 Video Sensor: Sensors shall meet the physical characteristics in Table 997-4. Cameras shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment.

Table 997-4 Performance Characteristics, Video Sensor	
Property	Requirements
Configuration	Displays detection zones, activations, overlaid on live video inputs.
Configuration	Editable detection zone size, placement, and sensitivity. Parameters stored in and retrieved from nonvolatile memory.
Processor	Video analysis, presence detection, data collection, storage and reporting of detection data.
Communications	TIA-232, 10/100 Base TX, FCC certified secure wireless, or cellular compatible with Agency's carrier. Department must approve carrier.
Communications	CDMA compatible
Solid State Detection Output	NEMA TS2, 6.5.2.26
Environmental Requirements	NEMA TS-2, Section 2.

997-3 TMS Non-Motorized Sensors.

997-3.1 General: Non-Motorized sensors include inductive loops, axle sensors, infrared, and video data collection technologies. Non-intrusive non-motorized sensors detect non-motorized vehicles and pedestrians using passive detection.

997-3.2Wire for Inductive Loops for Non-Motorized Data Collection: Materials used in the creation of the inductive loops must meet the material specification of No. 14 AWG International Municipal Signal Association (IMSA) 51-7 wire.

997-3.3 Axle Sensor for Non-Motorized Data Collection: Non-motorized Class I or II axle sensors shall meet the physical characteristics in Table 997-5.

Table 997-5 Physical Characteristics, Non-Motorized Axle Sensor	
Property	Requirements
Sensor Element Dimensions	3 ft. in length, 3/16 in. to 3/8 in. in diameter (varies by manufacturer)
Sensor Element Material	Pressure sensing piezoelectric
Pavement Operating Temperature Range	0°F to +150°F
Output Signal Range	Minimum +34 mV (front axle) and +65mV (rear axle), 220 lbs. Passenger bicycle, at 7.3 MPH
Environmental Requirements	NEMA TS-2-2016, Section 3.

997-3.4 Infrared for Non-Motorized Sensor Data Collection: Non-motorized infrared sensors shall meet the physical characteristics in Table 997-6.

Table 997-6 Physical Characteristics, Non-Motorized Infrared Sensor	
Property	Requirement
Temperature Sensitivity	2°F from ambient temp.
Detection Range	3 ft. to 18 ft.
Direction	Bidirectional
Operating Temperature Range	-13°F to 120°F

997-3.5. Video Sensor: Sensors shall meet the physical characteristics in Table 997-7. Cameras shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment.

Table 997-7 Performance Characteristics, Video Sensor	
Property	Requirements
Configuration	Displays detection zones, activations, overlaid on live video inputs.
Configuration	Editable detection zone size, placement, and sensitivity. Parameters stored in and retrieved from nonvolatile memory.
Processor	Video analysis, presence detection, data collection, storage and reporting of detection data.
Communications	TIA-232, 10/100 Base TX, FCC certified secure wireless, or cellular compatible with Agency's carrier. Department must approve carrier.
Solid State Detection Output	NEMA TS2-2021, 6.5.2.26
Environmental Requirements	NEMA TS-2, Section 2.

997-4 TMS Vehicle Sensors (Weight for Motorized Vehicle Data Collection).

997-4.1 General: Weight sensor arrays include inductive loops with strain gauge sensors or quartz piezoelectric sensors.

997-4.2 Wire for Inductive Loop: Materials used in the creation of the inductive loops must meet the material specification of No. 14 AWG International Municipal Signal Association (IMSA) 51-7 wire.

997-4.3 Strain Gauge Sensor: Weigh-In-Motion (WIM) systems utilize plates with strain gauges bonded to the underside or one-piece gauge strip scale. The strain gauge sensors shall meet the physical characteristics in Table 997-8.

Table 997-8 Physical Characteristics, Strain Gauge Sensor	
Property	Requirements
Sensor Size	.5 in. to 20 in. wide x 50 in. to 80 in. long
Operating Temperature Range	-50°F to 176°F
Scale Capacity	45,000 pounds per axle and overload protected to 8,0000 pounds per axle
Environmental Requirements	NEMA TS-2, Section 2.

997-4.4 Quartz Piezoelectric Sensor: Quartz piezoelectric sensors use one piece quartz crystal sensors to collect Weigh-In-Motion data. The quartz sensor shall meet the physical characteristics in Table 997-9.

Table 997-9 Physical Characteristics, Quartz Piezoelectric Sensor	
Property	Requirements
Measuring Range wheel load (At a referenced tire contact area)	0 to 34000 pounds (8 in. by 12.6 in.)
Overload (twin wheel)	55000 pounds
Sensitivity – Nominal	7.6 ± 12% pC/lbf
Sensitivity shift over sensor length	<± 3%
Threshold	<0.1 lbf
Linearity	<± 2% Full Scale Output
Hysteresis	≤ 2% Full Scale Output
Natural Frequency	> 5 kHz
Operating Temperature range	-40°F to 176°F
Temperature coefficient of sensitivity	-0.04%/°F
Operating Speed	5 MPH to 100 MPH
Insulation resistance	> 100 GΩ
Capacitance with 130 ft. cable	8 to 12 nF
Environmental Requirements	NEMA TS-2, Section 2

997-5 TMS Solar Power Unit for Motorized Data Collection.

997-5.1 General: Solar power unit consists of the following components: solar panel(s) and mounting hardware; 12 V storage battery; and voltage regulator with wiring and associated mounting hardware.

997-5.2 Solar Panel Configured for Nominal 12 V_{DC}: Solar panels cannot have internal voltage regulators and must be capable of multiple arrays and series or parallel wiring configurations. Meet the physical characteristics in Table 997-10:

Table 997-10 Physical Characteristics, Solar Panel	
Property	Requirements
Peak power range	85 to 300 watts
Voltage	Maximum power voltage greater than 16.5 V at 77°F
Current	Maximum power current greater than 2.85 A at 77°F
Photovoltaic modules construction	Mono or poly-crystalline cells
Efficiency Rating	Minimum 20%
Frame construction	Anodized aluminum
Mounting hardware construction	Anodized, galvanized or stainless-steel

997-5.3 Battery 12 V: Meet the physical characteristics in Table 997-11:

Table 997-11 Physical Characteristics, Battery 12 V	
Property	Requirements
Battery Chemistry	Rechargeable valve regulated lead-calcium gelled electrolyte or absorbed glass mat for photovoltaic applications
Case Construction	ABS Plastic or Polypropylene
Current discharge rate	Minimum of 100 hours at 0.9 amperes
Dimensions	Maximum of 12 inches by 8 inches by 10 inches

997-5.4 Voltage Regulator Configured for Nominal 12 V_{DC}: Meet the physical characteristics in Table 997-12:

Table 997-12 Physical Characteristics, Voltage Regulator	
Property	Requirements
Voltage for battery charging.	Minimum of 13.5 V_{DC}
Begin Charging-Battery Voltage	13.3 V or less
End Charging-Battery Voltage	Maximum of 14.5 V
Quiescent current	Maximum 15 mA
Charge rating	Minimum of 20 A.
Operating Temperature range	Range: 0 to 122°F
Dimensions	Approximately 2 inches by 5 inches by 1 inch.

997-6 TMS Solar Power Unit for Non-Motorized Data Collection.

997-6.1 General: Solar power unit consists of the following components: solar panel(s) and mounting hardware; 12 V storage battery; and voltage regulator with wiring and associated mounting hardware.

997-6.2 Solar Panel Configured for Nominal 12 V_{DC}: Solar panels cannot have internal voltage regulators and must be capable of multiple arrays and series or parallel wiring configurations. Meet the physical characteristics in Table 997-13.

Table 997-13 Physical Characteristics, Solar Panel	
Property	Requirements
Peak power range	65 to 300 watts
Voltage	Maximum power voltage greater than 16.5 V at 77°F
Current	Maximum power current greater than 2.85 A at 77°F
Photovoltaic modules construction	Mono or poly-crystalline cells
Efficiency Rating	Minimum 20%
Frame construction	Anodized aluminum
Mounting hardware construction	Anodized, galvanized, or stainless steel

997-6.3 Battery 12 V: Meet the physical characteristics in Table 997-14.

Table 997-14 Physical Characteristics, Battery 12 V	
Property	Requirements
Battery Chemistry	Rechargeable valve regulated lead-calcium gelled electrolyte or absorbed glass mat for photovoltaic applications
Case Construction	ABS Plastic or Polypropylene.
Current discharge rate	Minimum of 21 to 100 hours at 0.9 amperes
Dimensions	Maximum of 12 inches by 8 inches by 10 inches

997-6.4 Voltage Regulator Configured for Nominal 12 VDC: Meet the physical characteristics in Table 997-15.

Table 997-15 Physical Characteristics, Voltage Regulator	
Property	Requirements
Charging Voltage	Minimum of 13.5 V_{DC}
Begin Charging- Battery Voltage	13.3 V or less
End Charging- Battery Voltage	Maximum of 14.5 V
Quiescent current	Maximum 15 mA
Charge rating	Minimum of 20 amps
Operating Temperature range	Range: 0 to 122°F
Dimensions	2 inches by 5 inches by 1 inch

997-7 TMS System Communications Modem.

Meet the physical characteristics in Table 997-16. Modems shall be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment.

Table 997-16
Physical Characteristics, TMS Modem

Property	Requirements
Configuration	1.The device shall be field configurable to be powered from 12 VDC. 2.The device shall have the ability and be configured to utilize a network service that shall be at a minimum 4G LTE with fallback to 3G EV-DO.
Protocols: The device shall have the ability to utilize, at a minimum, the following protocols:	1. Network: TCP/IP, UDP/IP, Domain Name System (DNS) 2. Routing: Network Address Translation (NAT), Host Port Routing, DHCP, Point-to-Point Protocol over Ethernet (PPPoE), VLAN, Virtual Router Redundancy Protocol (VRRP), Reliable Static Route. 3. Application: Short Message Service (SMS), Telnet/SSH, Reverse Telnet, Simple Mail Transfer Protocol (SMTP), SNMP, SNTP, Reliable Static Route 4. Serial: TCP/UDP Packet Assembly Disassembly (PAD) Mode, Modbus (ASCII, RTU, Variable), Point-to-Point Protocol (PPP)
Communication Transmission	Code Division Multiple Access (CDMA) capable.
Event Reporting: The device shall have the capability to record and report, at a minimum, the following events in plain text:	1. Network parameters 2. Data usage 3. Power 4. Device temperature 5. Digital input 6. Global Positioning 7. System/Automatic 8. Vehicle Locator (GPS/AVL) 9. Timer
Security: The device shall have the following security provisions:	1. Ability to establish VPN tunnels. 2. IPsec, Secure Sockets Layer (SSL), and Generic Routing Encapsulation (GRE) VPN client 3. Port forwarding and Demilitarized Zone (DMZ) 4. Port filtering 5. Trusted IP 6. MAC address filtering
Operating Temperature range	Minimum 0 to 158°F
FCC Certification	FCC identification number displayed on an external label on the equipment

Table 997-16 Physical Characteristics, TMS Modem	
Property	Requirements
Number of SIM slots	Minimum of two SIM slots. SIM cards provided by the Department
Minimum Ethernet Port Speed	10/100 Base-TX

997-8 TMS Modem Antenna.

Meet the physical characteristics in Table 997-17.

Table 997-17 Physical Characteristics, TMS Modem Antenna	
Property	Requirements
Antenna Requirements	1. Dual diversity 2. Minimum NEMA rating of NEMA 3 3. Frequencies: F1 = 824 to 896 MHz, F2 = 1850 to 1990 MHz, F3 = 1850 to 1955 MHz, F4 = 1710 to 1770 MHz, F5 = 2110 to 2170 MHz 4. Voltage Standing Wave Ratio (VSWR) of 1.5:1 or less at resonant point 5. 50 Ω nominal impedance 6. Gain of 3.0 dB to 5.15 dB 7. Omni-directional radiation pattern 8. Vertical polarization 9. Glass-filled polypropylene radome 10. Adhesive mounting or Bolt mount 11. SMA male plug connectors 10 ft. (maximum)coaxial length 12. Antenna shall be compatible with the site modem

997-9 TMS Vehicle Speed/Classification Unit.

Vehicle speed/classification units must meet the physical characteristics in Tables 997-18 and 997-19. Unit must be compatible with the Department's polling software as listed in Table 997-20.

Table 997-18 Performance Characteristics, Vehicle Speed/Classification Unit	
Property	Requirements
Operations	Operates in an unattended mode, accumulating and locally storing real-time data allowing for later retrieval by downloading via the polling computer system. Capable of downloading through direct connection, serial or Ethernet, with a PC, without deleting or marking the files.

Table 997-18 Performance Characteristics, Vehicle Speed/Classification Unit	
Property	Requirements
Compatibility with software	Outputs data compatible with the Department's polling computer system. If non-compatible, then furnish a software module that converts the data into a format compatible with the Department's polling computer system.
Compatibility with sensors	Compatible with the weigh-in-motion sensors, embedded inductive loops, axle sensors, magnetometers and non-intrusive vehicle sensors in place at the Traffic Monitoring Site.
Count and Classification	Capable of determining the count and classification by type and speed of all vehicles for both directions of traffic on the roadway.
Functional Requirements	Capable of receiving input from two 6-foot by 6-foot embedded inductive loops, spaced 12 to 24 feet apart, leading edge to leading edge, with a single axle sensor located between the loops, in each lane of a six lane (minimum) roadway.
Functional Requirements	Capable of collecting data from each of the lanes of traffic in any combination of counts, classification, speed, or direction.
Electrical Components	Electrical components are designed to be solid-state so that they will not be damaged by jolts and vibrations encountered during shipping and everyday use.
Plug-In Modules	The vehicle speed/classification unit may be constructed utilizing plug in modules; however, when plug in modules are used, each vehicle speed/classification unit must be identical except for the number and type of modules used. Ensure that modules of the same type are identical and interchangeable.
Multiple Vehicle Speed/Classification Units in One Cabinet	Ensure that each vehicle speed/classification unit has a unique, individual unit number. The unit number must reside in non-volatile memory, so that it is not changed when a "cold or warm boot" is performed or by a power interruption.
Data Collection Requirement	Capable of obtaining and providing volume, speed, classification, and classification by speed data simultaneously.
Data Collection Requirement	Capable of obtaining and providing volume data by lane.
Data Collection Requirement	Capable of obtaining and providing speed data by lane in a minimum of 15 bins, programmable in 5 mph increments.

Table 997-18 Performance Characteristics, Vehicle Speed/Classification Unit	
Property	Requirements
Data Collection Requirement	Capable of obtaining and providing Classification by lane in vehicle type by axle class in 15 bins (minimum) in accordance with FHWA Classification Scheme "F" in Florida's Traffic Forecasting Handbook, Chapter 2, Figure 2.2 which can be accessed on the Department's website at the following URL address: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/planning/systems/systems-management/document-repository/traffic-analysis/2019-project-traffic-forecasting-handbook.pdf?sfvrsn=e105e71d_2.
Data Collection Requirement	Capable of obtaining and providing a minimum of 95% accuracy of vehicle class, speed and volume.
Data Collection Requirement	Capable of providing real-time monitoring of volume data by lane or direction in user selected intervals of as little as 15 minutes, when required, without disrupting the above selected programs
Communications	Capable of communicating directly with a PC or through a modem at a minimum rate of 19,200 bps.
Configuration	At a minimum, the following parameters are programmable by direct connection to the vehicle speed/classification unit by Ethernet or via modem: 1. Six-digit site number. 2. Number of lanes and directions. 3. Date and time. 4. Data operating and transmission parameters. 5. Sensor spacing. 6. Recording interval. 7. Vehicle parameter table with axle spacing ranges for each type of vehicle. 8. Number and range of speed categories, axle and length classifications, and headway.
Sensor Failure	The vehicle speed/classification unit must continue to provide the speed and/or volume from the remaining functioning sensors.
Sensitivity	The sensitivity level for each axle sensor must be individually adjustable using software, by direct PC connection and remotely via
Loop Detector	Loop detectors must be internal and self-tuning. The sensitivity level and any additional parameters necessary to prevent "loop crosstalk" for each embedded inductive loop must be individually adjustable using software, both by direct PC connection and remotely via telemetry.
Time Delay	A time delay, or "de-bounce" value for ignoring spurious axle signals (ghost axles) in the vehicle speed/classification unit software must be provided.

Table 997-18 Performance Characteristics, Vehicle Speed/Classification Unit	
Property	Requirements
Power	Provide a vehicle speed/classification unit that is field configurable to be powered 12 VDC and does not consume more than a total of 12 watts. If an internal battery is required, it must be capable of being recharged and shall be furnished and included with the vehicle speed/classification unit at no extra cost.
Mechanical	Provide a modular electronics unit which is completely enclosed in a durable housing of sheet metal or cast aluminum with a durable finish. When configured for operation the vehicle speed/classification unit including all cables must fit into a Type III cabinet.
Environmental (Ambient Temperature Range)	Provide an electronics unit which operates as specified when the ambient temperature and humidity inside the controller cabinet are within the following limits: The operating ambient temperature range must be between minus 0 to 140ºF. The rate of change in ambient temperature must not exceed 63ºF per hour, during which the relative humidity must not exceed 90%.
Environmental (Relative Humidity)	Provide an electronics unit which operates as specified when the ambient temperature and humidity inside the controller cabinet are within the following limits: The relative humidity must not exceed 90% over the temperature range of 40 to 109ºF. Above 109ºF, constant absolute humidity must be maintained as seen in Table 997-19. The relative humidity range shown in Table 997-19 is for dynamic testing.

Table 997-19 At 14.6 psi Barometric Pressure		
Dry Bulb ºF	Relative Humidity (%)	Wet Bulb ºF
40	75	37
50	80	46
60	83	57
70	86	66
80	87	77
90	89	88
100	89	97
109	90	108
120	70	109
130	50	109
140	38	109

Table 997-19 At 14.6 psi Barometric Pressure		
Dry Bulb ºF	Relative Humidity (%)	Wet Bulb ºF
150	28	109
160	21	109
165	18	109

Table 997-20 Performance Characteristics, Vehicle Speed/Classification Unit Polling Software	
Property	Requirements
Operations	Real time polling software operates on a PC using the Department's recommended operating system.
Communications	Communicates with the traffic counter/classifier and downloads data via cellular modem and produces reports of 15 minute, hourly, weekly, monthly and annual volume and classification data.
Configuration	Displays and enters operating parameters into the vehicle class/counter and allowing the display of real-time traffic volumes in addition to routine data collection activities.
Data Storage	Processes and stores all vehicle data retrieved in routine mode, regardless of the selected parameters.

997-10 TMS Vehicle Weigh in Motion Unit.

Weigh in Motion Unit must meet the physical characteristics in Tables 997-21 and 997-22. Polling software must meet the requirements in Table 997-23.

Table 997-21 Performance Characteristics, Vehicle Weigh in Motion Unit	
Property	Requirements
Operations	Operates in an unattended mode, accumulating data and locally storing real-time data allowing for later retrieval by downloading via the polling computer system. Capable of downloading through direct connection with a PC, without deleting or marking the files.
Compatibility with software	Outputs data compatible with the Department's polling computer system. If non-compatible, then furnish a software module that converts the data into a format compatible with the Department's polling computer system.
Compatibility with sensors	Compatible with the weigh-in-motion sensors, embedded inductive loops, axle sensors, and non-intrusive vehicle sensors in place at the Traffic Monitoring Site.
Count and Classification	Capable of determining the count and classification by type and speed of all vehicles for both directions of traffic on the roadway.
Functional Requirements	Capable of receiving input from a 6-foot by 6-foot (or 6-foot by 8-foot) embedded inductive loop, with four single WIM axle sensors located outside the loop, in each WIM lane of a six lane (minimum) roadway.

Table 997-21 Performance Characteristics, Vehicle Weigh in Motion Unit	
Property	Requirements
Functional Requirements	Capable of collecting data from each of the lanes of traffic in any combination of Weight, counts, classification, speed, or direction.
Electrical Components	Electrical components are designed to be solid-state so that they will not be damaged by jolts and vibrations encountered during shipping and everyday use.
Plug-In Modules	The vehicle Weigh in Motion unit may be constructed utilizing plug-in modules; however, when plug in modules are used, each vehicle Weigh in Motion unit must be identical except for the number and type of modules used. Ensure that modules of the same type are identical and interchangeable.
Multiple Vehicle Speed/Classification Units in One Cabinet	Ensure that each vehicle Weigh in Motion unit has a unique, individual unit number. The unit number must reside in non-volatile memory, so that it is not changed when a “cold or warm boot” is performed or by a power interruption.
Data Collection Requirement	Capable of obtaining and providing Weight, volume, speed, classification, and classification by speed data simultaneously.
Data Collection Requirement	Capable of obtaining and providing volume data by lane.
Data Collection Requirement	Capable of obtaining and providing speed data by lane in a minimum of 15 bins, programmable in 5 mph increments.
Data Collection Requirement	Capable of obtaining and providing Classification by lane in vehicle type by axle class in 15 bins (minimum) in accordance with FHWA Classification Scheme “F” in Florida’s Traffic Forecasting Handbook, Chapter 2, Figure 2.2 which can be accessed on the Department’s website at the following URL address: https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/planning/systems/systems-management/document-repository/traffic-analysis/2019-project-traffic-forecasting-handbook.pdf?sfvrsn=e105e71d_2.
Data Collection Requirement	Capable of obtaining and providing a minimum of 95% accuracy of vehicle weight, class, speed, and volume.
Data Collection Requirement	Capable of providing real-time monitoring of volume data by lane or direction in user selected intervals of as little as 15 minutes, when required, without disrupting the above selected programs
Communications	Capable of communicating directly with a PC or through a modem at a minimum rate of 19,200 bps.

Table 997-21 Performance Characteristics, Vehicle Weigh in Motion Unit	
Property	Requirements
Configuration	At a minimum, the following parameters are programmable by direct connection to the Weigh in Motion unit by Ethernet or via modem: 1. Six-digit site number. 2. Number of lanes and directions. 3. Date and time. 4. Data operating and transmission parameters. 5. Sensor spacing. 6. Recording interval. 7. Vehicle parameter table with axle spacing ranges for each type of vehicle. 8. Number and range of speed categories, axle and length classifications, and headway.
Sensor Failure	The Weigh in Motion unit must continue to provide the speed and/or volume from the remaining functioning sensors.
Sensitivity	The sensitivity level for each axle sensor must be individually adjustable using software, by direct PC connection and remotely via telemetry.
Loop Detector	Loop detectors must be internal and self-tuning. The sensitivity level and any additional parameters necessary to prevent “loop crosstalk” for each embedded inductive loop must be individually adjustable using software, both by direct PC connection and remotely via telemetry.
Time Delay	A time delay, or “de-bounce” value for ignoring spurious axle signals (ghost axles) in the vehicle speed/classification unit software must be provided.
Power	Provide a vehicle Weigh in Motion unit that is field configurable to be powered 12 VDC and does not consume more than a total of 12 watts. If an internal battery is required, it must be capable of being recharged and shall be furnished and included with the vehicle Weigh in Motion unit at no extra cost.
Mechanical	Provide a modular electronics unit which is completely enclosed in a durable housing of sheet metal or cast aluminum with a durable finish. When configured for operation the Weigh in Motion unit including all cables must fit into a Type III cabinet.
Environmental (Ambient Temperature Range)	Provide a Weigh in Motion unit which operates as specified when the ambient temperature and humidity inside the controller cabinet are within the following limits: The operating ambient temperature range must be between minus 0 to 140ºF. The rate of change in ambient temperature must not exceed 63ºF per hour, during which the relative humidity must not exceed 90%.

Table 997-21 Performance Characteristics, Vehicle Weigh in Motion Unit	
Property	Requirements
Environmental (Relative Humidity)	Provide a Weigh in Motion unit which operates as specified when the ambient temperature and humidity inside the controller cabinet are within the following limits: The relative humidity must not exceed 90% over the temperature range of 40 to 109ºF. Above 109ºF, constant absolute humidity must be maintained as seen in Table 997-22. The relative humidity range shown in Table 997-22 is for dynamic testing.

Table 997-22 At 14.6 psi Barometric Pressure		
Dry Bulb ºF	Relative Humidity (%)	Wet Bulb ºF
40	75	37
50	80	46
60	83	57
70	86	66
80	87	77
90	89	88
100	89	97
109	90	108
120	70	109
130	50	109
140	38	109
150	28	109
160	21	109
165	18	109

Table 997-23 Performance Characteristics, Department's Weigh in Motion Unit Polling Software	
Property	Requirements
Operations	Real time polling software operates on a PC using the Department's recommended operating system.
Communications	Communicates with the Weigh in Motion unit and downloading data via cellular modem and producing reports of 15 minute, hourly, weekly, monthly, and annual volume, weight, and classification data.

Table 997-23 Performance Characteristics, Department's Weigh in Motion Unit Polling Software	
Property	Requirements
Configuration	Displays and enters operating parameters into the vehicle Weigh in Motion unit and allows the display of real-time traffic volumes in addition to routine data collection activities.
Data Storage	Processes and stores all vehicle data retrieved in routine mode, regardless of the selected parameters.

997-11 TMS Non-Motorized Data Collection Units.

Non-Motorized data collection units must meet the physical characteristics in Tables 997-24. Polling software must meet the requirements in Table 997-25.

Table 997-24 Performance Characteristics, Classification Unit	
Property	Requirements
Operations	Operates in an unattended mode, accumulating data for later retrieval by downloading via the polling computer system. Capable of downloading through direct connection with a PC, without deleting or marking the files.
Operations	Non-motorized unit operating procedures.
Compatibility with software	Outputs data compatible with the Department's polling computer system. If non-compatible, then furnish a software module that converts the data into a format compatible with the Department's polling computer system.
Compatibility with sensors	Compatible with the embedded inductive loops, axle sensors, and non-intrusive vehicle sensors in place at the Traffic Monitoring Site.
Count, Speed and Classification	Capable of determining the count and classification (bicycle and pedestrian) by type for all directions of traffic on the sidewalk, side path, bicycle lane, and shared use path.
Functional Requirements	Capable of receiving input from embedded inductive loops, axle sensors, and non-intrusive sensors on the sidewalk, side path, bicycle lane, and shared use path.
Functional Requirements	Capable of collecting data from each direction of bicycle and pedestrian traffic in any combination of counts, classification, or direction.
Electrical Components	Electrical components are designed to be solid-state so that they will not be damaged by jolts and vibrations encountered during shipping and everyday use.

Table 997-24 Performance Characteristics, Classification Unit	
Property	Requirements
Plug-In Modules	The non-motorized data collection unit may be constructed utilizing plug-in modules; however, when plug in modules are used, each non-motorized data collection must be identical except for the number and type of modules used. Ensure that modules of the same type are identical and interchangeable.
Multiple Classification Units in One Cabinet	Ensure that each non-motorized data collection has a unique, individual unit number. The unit number must reside in non-volatile memory, so that it is not changed when a "cold or warm boot" is performed or by a power interruption.
Data Collection Requirement	Capable of obtaining and providing volume and classification data simultaneously.
Data Collection Requirement	Capable of obtaining and providing volume data by direction.
Data Collection Requirement	Capable of obtaining and providing a minimum of 80% accuracy of non-motorized classification and volume.
Communications	Capable of communicating directly with a PC or through a modem at a minimum rate of 115,200 bps.
Configuration	At a minimum, the following parameters are programmable by direct connection to the classification unit by Ethernet or via modem: 1. Six-digit alphanumeric site number. 2. Bicycle and pedestrian direction of travel. 3. Date and time. 4. Data operating and transmission parameters.
Sensor Failure	The non-motorized data collection unit must continue to provide the volume from the remaining functioning sensors.
Piezo Sensitivity	The sensitivity level for each axle sensor must be individually adjustable using software, by direct PC connection and remotely via telemetry.
Loop Detector	Loop detectors must be internal and self-tuning. The sensitivity level and any additional parameters necessary to prevent "loop crosstalk" for each embedded inductive loop must be individually adjustable using software, both by direct PC connection and remotely via telemetry.
Time Delay	A time delay, or "de-bounce" value for ignoring spurious axle signals (ghost axles) in the classification unit software must be provided.
Power	Provide a non-motorized data collection unit that is field configurable to be powered by 12 VDC and does not consume more than a total of 12 watts. If an internal battery is required, it must be capable of being recharged and shall be furnished and included with the non-motorized data collection unit at no extra cost.

Table 997-24 Performance Characteristics, Classification Unit	
Property	Requirements
Mechanical	Provide a modular electronics unit which is completely enclosed in a durable housing with a durable finish. When configured for operation the classification unit including all cables must fit into a Type III cabinet or self-contained in the manufacture's housing.
Environmental	Provide an electronics unit which operates as specified when the ambient temperature and humidity inside the controller cabinet are within the following limits: The operating ambient temperature range must be between minus 0 to 140ºF.

Table 997-25 Performance Characteristics of Non-Motorized Data Collection Polling Software	
Property	Requirements
Operations	Polling software operates on a PC using the Department's recommended operating system.
Operations	Software operating procedures.
Communications	Capable of communicating with the non-motorized data collection unit and downloading data via cellular modem and producing reports of hourly, weekly, monthly and annual volume and classification data.
Configuration	Capable of displaying and entering operating parameters into the non-motorized data collection unit and allowing the display of traffic volumes in addition to routine data collection activities.
Data Storage	Capable of processing and storing all non-motorized data retrieved in routine mode, regardless of the selected parameters.

997-12 Adhesive Bonding Agent.

Meet the requirements in Table 997-26.

Table 997-26 Physical Characteristics, Adhesive Bonding Agent	
Property	Requirements
Agent	Flowable mortar-based methyl methacrylate resin
Application	Per manufacturer's instruction.
Curing Time	Less than 60 minutes.
Gel Time	At 77ºF, 13 to 17 minutes
Tensile Strength	Greater than 2,000 psi

997-13 Loop Sealant for TMS.

Meet the requirements in Table 997-27.

Table 997-27 Physical Characteristics, Loop Sealant	
Property	Requirements
Agent	2-part unsaturated polyester resin utilizing a liquid methyl ethyl ketone peroxide (MEKP) hardener
Application	Per manufacturer's instruction. Hardener component amounts may be adjusted according to temperature and an accelerator is available for use in colder climates to further reduce drying time. Improper mixing may cause poor results.
Curing Time	Less than 60 minutes.
Gel Time	At 77°F, 10 to 25 minutes
Tensile Strength	Greater than 1,000 psi

997-14 TMS Cabinets.

Meet the requirements of Tables 997-28 and 997-29.

Table 997-28 Physical Characteristics, TMS Cabinet	
Property	Requirements
Cabinet Shell Material	0.125-inch-thick sheet aluminum Type 5052-H32
Weld Quality	Exterior seams are continuously welded, smooth, free of cracks, blow holes or other irregularities and the inside and outside edges are free of burrs.
Cabinet Finish	Outside surface of the cabinet has a smooth, uniform, and natural finish and the cabinet top has a sloped surface to prevent accumulation of water.
Cabinet Vent	Vent between the top of the door and the top of the cabinet, covered by screen material with a maximum opening of 0.125 inches.
Cabinet Door Hinge	Continuously hinged door constructed of 14-gauge stainless steel or 0.125 inches aluminum that occupies 80% of the front surface area of the cabinet and is rain and dust tight; hinged on the right side of the cabinet; hinge pin is stainless steel and capped at the top and bottom to deter tampering.
Cabinet Door	Double flanged on all four sides and equip it with a restraint that will hold the door open in the 90 degree and 120-degree position.

Table 997-28 Physical Characteristics, TMS Cabinet	
Property	Requirements
Cabinet Door Lock	Three point latching system, consisting of the following latch points: (1) Center of the cabinet - latching handle with provisions for a padlock in the center position (2) Top of the cabinet - controlled by the door handle (3) Bottom of the cabinet - controlled by the door handle Ensure that latching points (2) and (3) remain in the locked position until the latching handle is rotated to the unlocked position.
Cabinet Door Vent	Louvered vents meeting the NEMA rod entry test for 3R enclosures. The louvers are covered by a replaceable air filter mounted inside the cabinet door with either brackets or clamps that will allow easy removal and replacement.
Cabinet Shelf	Adjustable shelf, constructed of 0.08 inches thick aluminum, that is adjustable to within 15 inches of the top of the cabinet and to within 26 inches of the bottom of the cabinet in 2 inches increments.

Table 997-29 TMS Cabinet Dimensions			
	Cabinet Dimensions in Inches		
Cabinet Type	Height	Width	Depth
Type III	38”	23”	18”
Type IV	48”	30”	16”
Type V	56”	38”	27”

997-15 TMS Suppression Devices.

997-15.1 Power Suppression Devices: Meet the requirements of Table 997-30.

Table 997-30 Physical Characteristics, Power Suppression Devices	
Property	Requirements
Connector Type	Terminal Strip - plug in or screw type
Voltage	12 – 24 V_{DC}

997-15.2 Sensor Suppression Devices: Meet the requirements of Table 997-31.

Table 997-31 Physical Characteristics, Sensor Suppression Devices	
Property	Requirements
Connector Type	Terminal Strip - plug in or screw type
Voltage	6 V_{DC}

997-16 TMS Managed Field Ethernet Switch.

Meet the requirements of Table 997-32 and be compliant with the Code of Federal Regulations Section 200.216 Prohibition on certain telecommunications and video surveillance services or equipment.

Table 997-32
General Characteristics, Managed Field Ethernet Switch

Property	Requirements
Layer 2+ Capability	QoS, IGMP, rate limiting, security filtering
Transmission	Full Duplex, Half Duplex Ethernet communications
Error-free Operation	99.999%
Mean Time Between Failures	10 years or 87,600 hours, using Bellcore/Telcordia SR-332 standards
Networking Standards	IEEE 802.1Q, IEEE 802.1P, IEEE 802.3, IEEE 802.3u, IEEE 802.3x,
Optical Ports	Single Mode: 1,310 or 1,550 nanometers. Type ST or LC.
Optical Ports	1000 Base FX, with optical budget of at least 15dB. Minimum of four ports designed for use with two pair of fibers, two strands transmit, the other two strands receive.
Copper Ports	Minimum of four copper ports, Type RJ-45, auto-negotiate (10/100 Base), full duplex. IEEE 802.3 standard pinouts.
Operational Indicators	LEDs showing link, transmit, receive, and power.
Management Capability	Port-based VLAN, VLAN tagging, IEEE 802.1Q, 4-kilobit VLAN address table.
Management Capability	Forwarding/filtering rate at a minimum 14,880 packets per second for 10 megabits per second, and 148,800 packets per second for 100 megabits per second.
Management Capability	Minimum 4 kilobit MAC address table.
Management Capability	Support of, at a minimum, Version 2 of the Internet Group Management Protocol (IGMP).
Management Capability	Support of Secure Shell (SSH) and secure Web-based GUI.
Management Capability	Support of the Simple Network Management Protocol (SNMP) version 1/2/3. Accessible using the EIA-232 management port or telecommunication network.
Management Capability	Support of Remote Authentication Dial-In User Service (RADIUS) or Terminal Access Controller Access-Control System Plus (TACACS+).
Management Capability	Support of remote monitoring (RMON) of the Ethernet agent and the ability to switch monitoring (SMON).

Table 997-32 General Characteristics, Managed Field Ethernet Switch	
Property	Requirements
Management Capability	Support of Secure Copy (SCP) or Secure File Transfer Protocol (SFTP) and either Network Tim Protocol (NTP) or Simple Network Time Protocol (SNTP).
Management Capability	Supports port mirroring when combined with a network analyzer.
Power Requirements	Compatible with the solar requirements in 997-5.
Power Requirements	Fiber port fail open feature.
Environmental Requirements	NEMA TS 2 2021, Sections 2.2.7, 2.2.8., and 2.2.9.
Data Interface Compatibility	Compatible with the Vehicle Speed/Classification Unit, Weigh-In-Motion Unit, and Non-motorized Data Collection Unit.
Data Interface Compatibility	Compatible with the Department's polling software (TPAS).