DIVISION 9
MATERIALS

9-00 DEFINITIONS AND TESTS

9-00.1 Fracture

"Fractured aggregate is defined as an angular, rough, or broken surface of an aggregate particle created by crushing, or by other means. A face is considered a "fractured face" whenever one-half or more of the projected area, when viewed normal to that face, is fractured with sharp and well-defined edges: this excludes small nicks.

9-00.2 Wood Waste

Wood waste is defined as all material which, after drying to constant weight, has a specific gravity of less than 1.0.

9-00.3 Test for Mass of Galvanizing

At the option of the Engineer, the weight of zinc in ounce per square foot required by the various galvanizing specifications may be determined by an approved magnetic thickness gage suitably checked and demonstrated for accuracy, in lieu of the other methods specified.

9-00.4 Sieve Analysis of Aggregates

Sieve analysis for acceptance of aggregate gradation shall be performed by procedures described in the WAQTC FOP for AASHTO T 27/11.

9-00.5 Dust Ratio

The dust ratio is defined as the percent of material passing the U.S. No. 200 sieve divided by the percent of material passing the U.S. No. 40 sieve.

9-00.6 Sand/Silt Ratio

The sand/silt ratio is defined as the percent of material passing the U.S. No. 10 sieve divided by the percent of material passing the U.S. No. 200 sieve.

9-00.7 Galvanized Hardware, AASHTO M 232

An acceptable alternate to hot-dip galvanizing in accordance with AASHTO M 232 will be zinc coatings mechanically deposited in accordance with AASHTO M 298, providing the minimum thickness of zinc coating is not less than thats pecified in AASHTO M 232, and the process will not produce hydrogen embrittlement in the base metal. Sampling and testing will be made by the Engineer in accordance with commonly recognized national standards and methods used in the laboratory of the Department of Transportation.

9-00.8 Sand Equivalent

The sand equivalent will be the average of duplicate determinations from a single sample. The sand equivalent sample will be prepared in accordance with the WSDOT Field Operating Procedure (FOP) for AASHTO T 176.

For acceptance of processed material, there must be a clear line of demarcation. If no clear line of demarcation has formed at the end of the specified 20 minute sedimentation period, the material will be considered as failing to meet the minimum specified sand equivalent.

9-00.9 Field Test Procedures

Field test procedures may be either a WSDOT Standard Operating Procedure (SOP) or a Field Operating Procedure (FOP) for an AASHTO, ASTM, or WAQTC test procedure. A Field Operating Procedure is a technically equivalent abridged version of an AASHTO, ASTM or WAQTC test procedure for use in field conditions. References to manuals containing all of these tests and procedures can be found in Section 1-06.2(1).

9-01 PORTLAND CEMENT

9-01.1 Types of Cement

Cement shall be classified as Portland cement or blended hydraulic cement.

9-01.2 Specifications

9-01.2(1) Portland Cement

Portland cement shall conform to the requirements for Types I, II, or III cement of the Standard Specifications for Portland Cement, AASHTO M 85 or ASTM C 150, except that the content of alkalis shall not exceed 0.75 percent by weight calculated as Na_20 plus 0.658 K_20 and except that the content of Tricalcium aluminate (C_3A) shall not exceed 8 percent by weight calculated as $2.650A1_20_3$ minus $1.692Fe_20_3$. The total amount of processing additions used shall not exceed 1% of the weight of portland cement clinker. The type and amount of processing additions used shall be shown on mill test reports.

The time of setting shall be determined by the Vicat Test method, AASHTO T 131 or ASTM C 191.

9-01.2(3) Low Alkali Cement

When the Special Provisions state that low alkali cement shall be used, the percentage of alkalis in the cement shall not exceed 0.60 percent by weight calculated as Na20 plus 0.658 K20. This limitation shall apply to all types of Portland cement.

9-01.2(4) Blended Hydraulic Cement

Blended hydraulic cement shall be either Type IP (MS), Type I (SM) (MS) or Type I (PM) (MS) cement conforming to AASHTO M 240 and meet the following additional requirements:

1. Type IP(MS) Portland - Pozzolan Cement with moderate sulfate resistance.

   This product shall be limited to Portland Cement and Pozzolan. Pozzolan shall be limited to fly ash or ground granulated blast furnace slag. Fly ash is limited between 15 percent and 35 percent by weight of the cementitious material. Ground granulated blast furnace slag is limited between 15 percent and 25 percent by weight of the cementitious material.

2. Type I(SM) (MS) Slag Modified Portland Cement with moderate sulfate resistance.

   This product shall be limited to Portland Cement and ground granulated blast furnace slag. The addition of ground granulated blast furnace slag shall be limited to a maximum of 25 percent by weight of the cementitious material.

3. Type I(PM)(MS) Pozzolan – Modified Portland Cement with moderate sulfate resistance.

   The product shall be limited to Portland Cement and pozzolan. The pozzolan shall be limited to fly ash or ground granulated blast furnace slag at a maximum of 15 percent by weight of the cementitious material.

The source and weight of the fly ash or ground granulated blast furnace slag shall be certified on the cement mill test certificate and shall be reported as a percent by weight of the total cementitious material. The fly ash or ground granulated blast furnace slag constituent content in the finished cement will not vary morethan plus or minus 5 percent by weight of the finished cement from the certified value.

Fly ash shall meet the requirements of Section 9-23.9 of these Standard Specifications.

Ground granulated blast furnace slag shall meet the requirements of Section 9-23.10 of these Standard Specifications.

9-01.3 Tests and Acceptance

Cement may be accepted by the Engineer based on the Manufacturer's Mill Test Report number indicating full conformance to the Specifications. All shipments of the cement to the Contractor or concrete supplier shall identify the applicable Mill Test Report Number. The concrete supplier or Contractor shall provide mill test identification on all concrete deliveries.

Each mixing facility or plant utilizing Portland cement shall be equipped with a suitable means or device for obtaining a representative sample of the cement. The device shall enable the sample to be readily taken in proximity to the cement weigh hopper and from a container or conveyor holding only cement.

Cement may be tested using samples taken at the job site by the Engineer for submission to the State Materials Laboratory for testing.

9-01.4 Storage on the Work Site

The cement shall be stored on the site in a manner as to permit easy access for inspection and identification.

Cement shall be adequately protected at all times from rain and dampness. Cement which, in the opinion of the Engineer, contains lumps that will not be pulverized in the mixer shall be rejected.

Type III Portland cement stored by the Contractor for a period longer than 30 days, or Types I or II Portland cement stored by the Contractor for a period longer than 60 days, shall be held for retest. If the cement has lost strength during the period of storage, as shown by tests of the Contracting Agency, sufficient additional cement shall be added to the mix at the Contractor's expense to overcome such loss, or the cement may be rejected. The amount of cement to be added to the mix shall be determined by the Engineer.

9-02 BITUMINOUS MATERIALS

9-02.1 Asphalt Material, General

Asphalt furnished under these Specifications shall not have been distilled at a temperature high enough to injure by burning or to produce flecks of carbonaceous matter, and upon arrival at the work, shall show no signs of separation into lighter and heavier components.

9-02.1(1) Vacant

9-02.1(2) Medium Curing (MC) Liquid Asphalt

Characteristics		AASHTO Test Method	MC-70	MC-250	MC-800	MC-3000
Kinematic Viscosity at 140ºF cSt		T 201	70-140	250-500	800-1600	3000-6000
Flash Point (Tag Open Cup)	Min. F	T 79	100	150	150	150
Water Content	Min. %	T 55	0.2	0.2	0.2	0.2
Distillation: volume % of total distillate to 680ºF		T 78				
to 437ºF			0-20	0-10	---	---
to 500ºF			20-60	15-55	0-35	0-15
to 600ºF			65-90	60-87	45-80	15-75
Residue of 680ºF distillation % volume by difference	Min.		55	67	75	80
Properties of residue from distillation to 680ºF Absolute viscosity at 140ºF, poise		T 202	300-1200	300-1200	300-1200	300-1200
[1]Ductility, 5 cm/min. at 77ºF, cm	Min.	T 51	100	100	100	100
Solubility in trichloroethylene	Min. %	T 44	99.0	99.0	99.0	99.0

[1]If the ductility at 77ºF is less than 100, the material will be acceptable if its ductility at 60ºF is more than 100.

The material shall not foam when heated to the application temperature recommended in Section 5-02.3(3).

9-02.1(3) Rapid Curing (RC) Liquid Asphalt

Characteristics		AASHTO Test Method	RC-70	RC-250	RC-800	RC-3000
Kinematic Viscosity at 140ºF cSt		T 201	70-140	250-500	800-1600	3000-6000
Flash Point (Tag Open Cup)	Min. F	T 79	---	80	80	80
Water Content	Min. %	T 55	0.2	0.2	0.2	0.2
Distillation: volume % of total distillate to 680ºF		T 78				
to 374ºF	Min.		10	---	---	---
to 473ºF	Min.		50	35	15	---
to 500ºF	Min.		70	60	45	25
to 600ºF	Min.		85	80	75	70
Residue of 680ºF distillation % volume by difference	Min.		55	65	75	80
Properties of residue from distillation to 680ºF Absolute viscosity at 140ºF, poise		T 202	600-2400	600-2400	600-2400	600-2400
Ductility, 5 cm/min. at 77ºF	Min.	T 51	100	100	100	100
Solubility in trichloroethylene	Min. %	T 44	99.0	99.0	99.0	99.0

The material shall not foam when heated to application temperature recommended in Section 5-02.3(3).

9-02.1(4) Asphalt Binders

Asphalt binder meeting the requirements of AASHTO M 320 of the grades specified in the contract shall be used in the production of HMA.

9-02.1(4)A Performance Graded Asphalt Binder

Performance Grade	PG58			PG64			PG70			PG76	
	-22	-28	-34	-22	-28	-34	-22	-28	-34	-22	-28
Original Binder											
Flash point temp, AASHTO T48 Minimum °C	230										
Viscosity, AASHTO T316 Maximum 3 Pa·s, test temp, °C	135										
Dynamic shear, AASHTO T315 G*/sinδ, minimum 1.00 kPa Test temp. @ 10 rad/s, °C	58			64			70			76	
Rolling Thin Film Oven Residue (AASHTO T240)											
Mass Change, Maximum, percent	1.00										
Dynamic shear, AASHTO T315 G*/sinδ, minimum 2.20 kPa Test temp. @ 10 rad/s, °C	58			64			70			76	
Pressure Aging Vessel Residue (AASHTO R28)											
PAV aging temperature, °C	100										
Dynamic shear, AASHTO T315 G*sinδ, maximum 5000 kPa Test temp. @ 10 rad/s, °C	22	19	16	25	22	19	28	25	22	31	28
Creep stiffness, AASHTO T313 S, maximum 300 MPa, m - value, minimum 0.300 Test temp. @ 60 s, °C	-12	-18	-24	-12	-18	-24	-12	-18	-12	-12	-18

All Performance Grade asphalt binders not included in this chart shall be determined by Table 1-Performance Graded Asphalt Binder Specification in AASHTO M320.

Grade	Type AASHTO Test Method	Cationic Emulsified Asphalt: Rapid Setting CRS-1 Min.	CRS-1 Max	CRS-2 Min.	CRS-2 Max.	Medium Setting CMS-2S Min.	CMS-2S Max.	CMS-2 Min.	CMS-2 Max.	CMS-2h Min.	CMS-2h Max.	Slow Setting CSS-1 Min.	CSS-1 Max.	CSS-1h Min.	CSS-1h Max.	Special Tack STE-1 Min.	STE-1 Max.
Tests on Emulsions:																	
Viscosity Saybolt Furol S @ 77ºF (25 °C)	T 59	—	—	—	—	—	—	—	—	—	—	20	100	20	100	—	30
Viscosity Saybolt Furol S @ 122ºF (50 °C)	T 59	20	100	150	400	50	450	50	450	50	450	—	—	—	—	—	—
Storage stability test 1 day %	T 59	—	1	—	1	—	1	—	1	—	1	—	1	—	1	—	1
Demulsibility 35 ml 0.8% sodium dioctyl sulfosuccinate, %[a]	T 59	40	—	40	—	—	—	—	—	—	—	—	—	—	—	25	—
Coating ability & water resistance:																	
Coating, dry aggregate	T 59	—	—	—	—	Good	—	Good	—	Good	—	—	—	—	—	—	—
Coating, after spraying	T 59	—	—	—	—	Fair	—	Fair	—	Fair	—	—	—	—	—	—	—
Coating, wet aggregate	T 59	—	—	—	—	Fair	—	Fair	—	Fair	—	—	—	—	—	—	—
Coating, after spraying	T 59	—	—	—	—	Fair	—	Fair	—	Fair	—	—	—	—	—	—	—

Cationic Emulsified Asphalt (Continued)

Grade	Type AASHTO Test Method	Rapid Setting CRS-1 Min.	Rapid Setting CRS-1 Max	Rapid Setting CRS-2 Min.	Rapid Setting CRS-2 Max	Medium Setting CMS-2S Min.	Medium Setting CMS-2S Max	Medium Setting CMS-2 Min.	Medium Setting CMS-2 Max	Medium Setting CMS-2h Min.	Medium Setting CMS-2h Max	Slow Setting CSS-1 Min.	Slow Setting CSS-1 Max	Slow Setting CSS-1h Min.	Slow Setting CSS-1h Max	Special Tack STE-1 Min.	Special Tack STE-1 Max
Particle charge test	T 59	Pos		Pos		Pos		Pos		Pos		Pos[b]		Pos[b]		Pos	
Sieve Test, %	T 59	—	0.10	—	0.10	—	0.10	—	0.10	—	0.10	—	0.10	—	0.10	—	0.10
Cement mixing test, %	T 59	—	—	—	—	—	—	—	—	—	—	—	2.0	—	2.0	—	—
Distillation:																	
Oil distillate by vol. of emulsions %	T 59	—	3	1.5	3	—	20	—	12	—	12	—	—	—	—	—	5
Residue, %	T 59	60	—	65	—	60	—	65	—	65	—	57	—	57	—	45	—
Tests on residue from distillation tests:																	
Penetration, 77ºF (25° C)	T 49	100	250	100	250	100	250	100	250	40	90	100	250	40	90	100	200
Ductility, 77ºF (25° C) 5 cm/min., cm	T 51	40	—	40	—	40	—	40	—	40	—	40	—	40	—	40	—
Solubility in trichloroethylene, %	T 44	97.5	—	97.5	—	97.5	—	97.5	—	97.5	—	97.5	—	97.5	—	97.5	—

[a]The demulsibility test shall be made within 30 days from date of shipment.

[b]If the particle charge test for CSS-1 and CSS-1h is inconclusive, material having a maximum pH value of 6.7 will be acceptable.

9-02.1(5) Vacant

9-02.1(6) Cationic Emulsified Asphalt

See table. Pages 9-9 and 9-10.

9-02.1(6)A Polymerized Cationic Emulsified Asphalt CRS-2P

The asphalt CRS-2P shall be a polymerized cationic emulsified asphalt. The polymer shall be milled into the asphalt or emulsion during the manufacturing of the emulsion. The asphalt CRS-2P shall meet the following specifications:

	AASHTO Test Method	Specifications	
		Minimum	Maximum
Viscosity @122ºF, SFS	T 59	100	400
Storage Stability 1 day %	T 59	---	1
Demulsibility 35 ml. 0.8% Dioctyl Sodium Sulfosuccinate	T 59	40	---
Particle Charge	T 59	positive	---
Sieve Test %	T 59	---	0.30
Distillation			
Oil distillate by vol. of emulsion %	T 59[note 1]	0	3
Residue	T 59	65	---
Test on the Residue From Distillation			
Penetration @77ºF	T 49	100	250
Torsional Recovery %	[note 2]	18	---
or			
Toughness/Tenacity in-lbs	[note 3]	50/25	---

[note 1]Distillation modified to use 300 grams of emulsion heated to 350ºF ± 9ºF and maintained for 20 minutes.

[note 2]The Torsional Recovery test shall be conducted according to the California Department of Transportation Test Method No. 332.

[note 3]Benson method of toughness and tenacity; Scott tester, inch-pounds at 77ºF, 20 in. per minute pull. Tension head $^{7}/_{8}$ in. diameter.

At the option of the supplier the Benson Toughness/Tenacity test can be used in lieu of Torsional Recovery based on type of modifier used. If the Benson Toughness/Tenacity method is used for acceptance the supplier must supply all test data verifying specification conformance.

9-02.1(7) Asphalt for Sub-Sealing

Asphalt for sub-sealing shall conform to the requirements of ASTM D 3141 except that the minimum softening point shall be 170ºF.

9-02.1(8) Flexible Bituminous Pavement Marker Adhesive

Flexible bituminous pavement marker adhesive is a hot melt thermoplastic bituminous material used for bonding raised pavement markers and recessed pavement markers to the pavement.

The adhesive material shall conform to the following requirements:

Property	Test Method	Requirement
Penetration, 77ºF, 100g, 5 sec, dmm	AASHTO T 49	30 Max.
Softening Point, F	AASHTO T 53	200 Min.
Rotational Thermosel Viscosity, cP, #27 spindle, 20 RPM, 400ºF	AASHTO T 316	5000 Max.
Ductility, 77ºF, 5 cm/minute, cm	AASHTO T 51	15 Min.
Ductility, 39.2ºF, 1 cm/minute, cm	ASTM D 51	5 Min.
Flexibility, 1", 20ºF, 90 deg. Bend, 10 sec., $^1/_8$"× 1" × 6" specimen	ASTM D 3111 NOTE 1	Pass

Flexible bituminous adhesive shall develop bond pull-off strength greater than 50 psi when tested in accordance with WSDOT T-426.

Note 1: Flexibility test is modified by bending specimen through an arc of 90 degrees at a uniform rate in 10 seconds over a 1-inch diameter mandrel.

9-02.1(9) Coal Tar Pitch Emulsion

The coal tar pitch emulsions shall conform to the requirements found in ASTM D 5727. The emulsion shall be homogeneous and shall show no separation or coagulation of components that cannot be overcome by moderate stirring. It shall be capable of being applied completely by squeegee, brush, or other approved mechanical methods to the surface of bituminous pavements when spread at the specified rates.

9-02.2 Sampling and Acceptance

9-02.2(1) Certification of Shipment

Bituminous materials may be accepted by the Engineer based on the asphalt binder supplier's Certification of Compliance incorporated in their Bill of Lading. The Certification will include a statement certifying specification compliance for the product shipped. Failure to provide this Certification with the shipment shall be cause for rejection of the material. The following information is required on the Bill of Lading:

1. Date
2. Contract Number and/or Project Name
3. Grade of Commodity and Certification of Compliance
4. Anti-strip Type
5. Percent Anti-strip
6. Mass (Net Tons)
7. Volume (Gross Gallons)
8. Temperature of Load (F)
9. Bill of Lading Number

10. Consignee and Delivery Point
11. Signature of Supplier's Representative
12. Supplier (Bill of Lading Generator)
13. Supplier's Address
14. Refiner
15. Refiner's Location

The Bill of Lading shall be supplied at the time of shipment of each truck load, truck and trailer, or other lot of asphalt binder. In addition to the copies the Contractor requires, one copy of the Bill of Lading including the Certification Statement shall be sent with the shipment for agency use.

9-02.2(2) Samples

When requested by the Engineer, the asphalt supplier shall ship, by prepaid express or U.S. mail, samples of asphalt that represent current production.

9-02.3 Temperature of Asphalt

The temperature of paving asphalts in storage tanks when loaded for transporting shall not exceed the maximum temperature recommended by the asphalt binder manufacturer.

9-02.4 Anti-Stripping Additive

When directed by the Engineer, heat-stable anti-stripping additive shall be added to the asphalt mix. At the option of the Contractor, the anti-stripping additive can be either added to the liquid asphalt or sprayed on the aggregate on the cold feed. Once the process and type of anti-stripping additive proposed by the Contractor have been approved by the State Materials Laboratory, the process, brand, grade, and amount of anti-stripping additive shall not be changed without approval of the Engineer.

When liquid anti-stripping additive is added to the liquid asphalt, the amount will be designated by the Engineer, but shall not exceed 1 percent by weight of the liquid asphalt.

When polymer additives are sprayed on the aggregate, the amount will be designated by the Engineer, but shall not exceed 0.67 percent by weight of the aggregate.

The use of another process or procedure for adding anti-stripping additive to the asphalt mix will be considered based on a proposal from the Contractor.

9-03 AGGREGATES

9-03.1 Aggregates for Portland Cement Concrete

9-03.1(1) General Requirements

Portland cement concrete aggregates shall be manufactured from ledge rock, talus, or sand and gravel in accordance with the provisions of Section 3-01.

Aggregates tested in accordance with AASHTO T 303 or ASTM C 1260 with expansion greater than 0.20 percent are Alkali Silica Reactive (ASR) and will require mitigating measures. Aggregates tested in accordance with ASTM C 1293 with expansion greater than 0.04 percent are Alkali Silica Reactive (ASR) and will require mitigating measures.

Aggregates for use in Commercial Concrete as defined in 6-02.3(2)B shall not require mitigation.

Mitigating measures for aggregates with expansions from 0.21 to 0.45 percent, when tested in accordance with AASHTO T 303 or ASTM C 1260, may be accomplished by using low alkali cement as per 9-01.2(3) or by using 25% Class F fly ash by total weight of the cementitious materials. The Contractor may submit an alternative mitigating measure through the Project Engineer to the State Materials Laboratory for approval along with evidence in the form of test results from AASHTO T 303 or ASTM C 1260 that demonstrate the mitigation when used with the proposed aggregate controls expansion to 0.20 percent or less. The agency may test the proposed ASR mitigation measure to verify its effectiveness. In the event of a dispute, the agency's results will prevail.

Mitigating measures for aggregates with expansions greater than 0.45 percent when tested in accordance with AASHTO T-303 or ASTM C-1260 shall include the use of low alkali cement per 9-01.2(3) and may include the use of fly ash, lithium compound admixtures, ground granulated blast furnace slag or other material as approved by the Engineer. The Contractor shall submit evidence in the form of test results from ASTM C 1260 or AASHTO T 303 through the Project Engineer to the State Materials Laboratory that demonstrate the proposed mitigation when used with the aggregates proposed will control the potential expansion to 0.20 percent or less before the aggregate source may be used in concrete. The agency may test the proposed ASR mitigation measure to verify its effectiveness. In the event of a dispute, the agency's results will prevail.

Passing petrographic analysis (ASTM C 295) accepted by WSDOT prior to August 1, 2005, is acceptable as proof of mitigation until the aggregate source is reevaluated.

ASTM C 1293 sampling and testing must be coordinated through the WSDOT State Materials Laboratory, Documentation Section utilizing the ASA (Aggregate Source Approval) process. Cost of sampling, testing, and processing will be borne by the source owner.

9-03.1(2) Fine Aggregate for Portland Cement Concrete

Fine aggregate shall consist of sand or other inert materials, or combinations thereof, approved by the Engineer, having hard, strong, durable particles free from adherent coating. Fine aggregate shall be washed thoroughly to remove clay, loam, alkali, organic matter, or other deleterious matter.

9-03.1(2)A Deleterious Substances

The amount of deleterious substances in the washed aggregate shall not exceed the following values:

1. Particles of specific gravity less than 1.95 ..... 1.0 percent by weight.
2. Organic matter, by colorimetric test, shall not be darker than the reference standard color (organic plate No. 3) AASHTO T 21 unless other tests prove a darker color to be harmless.

9-03.1(2)B Grading

Fine aggregate shall be graded to conform to the following requirements expressed as percentages by weight:

	Class 1 Percent Passing		Class 2 Percent Passing	
Sieve Size	Min.	Max.	Min.	Max.
⅜″ square	100		100	
U.S. No. 4	95	100	95	100
U.S. No. 8	68	86	---	---
U.S. No. 16	47	65	45	80
U.S. No. 30	27	42	---	---
U.S. No. 50	9	20	10	30
U.S. No. 100	0	7	2	10
U.S. No. 200	0	2.5	0	2.5

For fine aggregate Class 1, individual test variations under the minimum or over the maximum will be permitted as follows, provided the average of three consecutive tests is within the specification limits:

Sieve Size	Permissible Percent of Variation in Individual Tests
U.S. No. 30 and coarser	2
U.S. No. 50 and finer	0.5

Within the gradation limits for fine aggregate Class 2, uniformity of gradation shall be limited to a range of plus or minus 0.20 of the reference fineness modulus. The reference fineness modulus shall be determined from a representative sample from the proposed source as submitted by the Contractor.

9-03.1(2)C Use of Substandard Gradings

Fine aggregate with more than the maximum percentage passing any sieve may be accepted provided the cement content of the finished concrete is increased at the Contractor's expense, $^1/_3$ percent for each 1 percent the fine aggregate passing each sieve is in excess of the maximum.

Under no circumstances shall fine aggregate Class 1 be used which has a grading finer than the following:

Sieve Size	Percent Passing
U.S. No. 8	95
U.S. No. 16	80
U.S. No. 30	60
U.S. No. 50	25
U.S. No. 200	2.5

All percentages are by weight.

9-03.1(3) Vacant

9-03.1(4) Coarse Aggregate for Portland Cement Concrete

Coarse aggregate for concrete shall consist of gravel, crushed stone, or other inert material or combinations thereof having hard, strong, durable pieces free from adherent coatings. Coarse aggregate shall be washed to remove clay, silt, bark, sticks, alkali, organic matter, or other deleterious material.

9-03.1(4)A Deleterious Substances

The amount of deleterious substances shall not exceed the following values:

Amount finer than U.S. No. 200	1.00 percent by weight
Pieces of specific gravity less than 1.95	2.00 percent by weight
Clay lumps	0.50 percent by weight
Shale	2.00 percent by weight
Wood waste	0.05 percent by weight

For coarse aggregate with a minimum single face fracture content of 25 percent by weight, the material finer than the U.S. No. 200 sieve may increase to a maximum of 1.5 percent by weight. The fracture requirement shall be at least one fractured face and will apply to the combined aggregate retained on the U.S. No. 4 sieve in accordance with FOP for AASHTO PT 61.

9-03.1(4)B Wear in Los Angeles Machine

Coarse aggregate shall not have a percentage of wear in Los Angeles machine in excess of 35 after 500 revolutions.

9-03.1(4)C Grading

Coarse aggregate for Portland cement concrete when separated by means of laboratory sieves shall conform to one or more of the following gradings as called for elsewhere in these Specifications, Special Provisions, or in the Plans:

Passing	AASHTO Grading No. 467		AASHTO Grading No. 57		AASHTO Grading No. 67		AASHTO Grading No. 7		AASHTO Grading No. 8	
Sieve Size	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
2″ square	100	—	—	—	—	—	—	—	—	—
1½″ square	95	100	100	—	—	—	—	—	—	—
1″ square	—	—	95	100	100	—	—	—	—	—
¾″ square	35	70	—	—	90	100	100	—	—	—
½″ square	—	—	25	60	—	—	90	100	100	—
⅜″ square	10	30	—	—	20	55	40	70	85	100
U.S. No. 4	0	5	0	10	0	10	0	15	10	30
U.S. No. 8	—	—	0	5	0	5	0	5	0	10
U.S. No. 16	—	—	—	—	—	—	—	—	0	5

All percentages are by weight.

In individual tests, a variation of four under the minimum percentages or over the maximum percentages will be permitted, provided the average of three consecutive tests is within the specification limits. Coarse aggregate shall contain no piece of greater size than two times the maximum sieve size for the specified grading measured along the line of greatest dimension.

When the Engineer approves, the coarse aggregate may be blended from other sizes if:

1. The resulting aggregate meets all requirements for the approved grading;
2. Each size used makes up at least 5 percent of the blend; and
3. The Contractor supplies the Engineer with gradings for the proposed sizes, along with their proper proportions.

9-03.1(5) Combined Aggregate Gradation for Portland Cement Concrete

As an option to using Coarse and Fine graded aggregates for Portland Cement Concrete, aggregate gradation may consist of a combined gradation. Aggregates shall consist of sand, gravel, crushed stone, or other inert material or combinations thereof, having hard, strong durable particles free from adherent coatings. Aggregates shall be washed to remove clay, loam, alkali, organic matter, silt, bark, sticks, or other deleterious matter.

9-03.1(5)A Deleterious Substances

The amount of deleterious substances in the washed aggregate shall not exceed the following values:

1. Particles of specific gravity less than 1.95 — 2.0 percent by weight
2. Organic matter, by colorimetric test, shall not be darker than the reference Standard color (organic plate No. 3) AASHTO T21 unless other tests prove a darker color to be harmless.

3. Aggregates retained on the U.S. No. 4 sieve shall not have a percentage of wear in Los Angeles machine in excess of 35 after 500 revolutions.
4. Clay lumps — 0.3 percent by weight
5. Shale — 1.00 percent by weight
6. Wood Waste — 0.03 percent by weight
7. Amount finer than U.S. No. 200 sieve — 2.0 percent by weight

9-03.1(5)B Grading

If a nominal maximum aggregate size is not specified, the Contractor shall determine the nominal maximum aggregate size, using ACI 211.1 as a guide. In no case will the maximum aggregate size exceed one-fifth of the narrowest dimension between sides of the forms, one-third the depth of slabs, nor three-fourths of the minimum clear spacing between individual reinforcing bars, bundles of bars, or pretensioning strands.

The combined aggregate shall conform to the following requirements based upon the nominal maximum aggregate size.

Nominal Maximum Aggregate Size	1-1/2	1	3/4	1/2	3/8	No. 4
2″ square	100					
1 1/2″ square	87-100*	100				
1″ square		82-100*	100			
3/4″ square	62-88		87-100*	100		
1/2″ square		57-83		81-100*	100	
3/8″ square	43-64		60-88		86-100*	100
U.S. No. 4	29-47	34-54	41-64	48-73		68-100*
U.S. No. 8	19-34	22-39	27-47	31-54	39-73	
U.S. No. 16	12-25	14-29	17-34	20-39	24-54	28-73
U.S. No. 30	7-18	8-21	9-25	11-29	13-39	16-54
U.S. No. 50	3-14	3-15	4-18	5-21	6-29	7-39
U.S. No. 100	0-10	0-11	0-14	0-15	0-21	0-29
U.S. No. 200	0-2.0	0-2.0	0-2.0	0-2.0	0-2.0	0-2.0

* = Nominal Maximum Size

All percentages are by weight.

Nominal maximum size for concrete aggregate is defined as the smallest standard sieve opening through which the entire amount of the aggregate is permitted to pass. Standard sieve sizes shall be those listed in ASTM C 33.

The Contracting Agency may sample each component aggregate prior to introduction to the weigh batcher or as otherwise determined by the Engineer. Each separate component will be sieve analyzed alone per AASHTO Test Method T-11/27. All material components will be mathematically re-combined by proportions (Weighted Average), supplied by the Contractor.

9-03.2 Vacant

9-03.3 Vacant

9-03.4 Aggregate for Bituminous Surface Treatment

9-03.4(1) General Requirements

Aggregate for bituminous surface treatment shall be manufactured from ledge rock, talus, or gravel, in accordance with Section 3-01, which meets the following test requirements:

Los Angeles Wear, 500 Rev.	35% max.
Degradation Factor	30 min.

9-03.4(2) Grading and Quality

Aggregate for bituminous surface treatment shall conform to the requirements in the table below for grading and quality. The particular type or grading to be used shall be as shown in the Plans. All percentages are by weight.

The material shall meet the requirements for grading and quality when placed in hauling vehicles for delivery to the roadway, or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

	Crushed Cover Stone Percent Passing	Crushed Screening Percent Passing				
		¾″-½″	⅝″-US No. 4	½″-US No. 4	⅜″- US NO. 10	US No. 4-0″
1″ square	---	100	---	---	---	---
¾″ square	100	95-100	100	---	---	---
⅝″ square	95-100	---	95-100	100	---	---
½″ square	---	0-20	---	95-100	100	---
⅜″ square	---	0-5	---	---	90-100	100
U.S. No. 4	20-45	---	0-10	0-15	30-56	76-100
U.S. No. 10	---	---	0-3	0-3	0-10	30-60
U.S. No. 200	0-7.5	0-1.5	0-1.5	0-1.5	0-1.5	0-10.0
% fracture, by weight, min.	75	75	75	75	75	75
Sand equivalent min.	40	---	---	---	---	---
Static Stripping Test	Pass	Pass	Pass	Pass	Pass	Pass

All percentages are by weight.

The fracture requirement shall be at least one fractured face and will apply to the combined aggregate retained on the U.S. No. 4 sieve in accordance with FOP for AASHTO PT 61.

The finished product shall be clean, uniform in quality, and free from wood, bark, roots, and other deleterious materials.

Crushed screenings shall be substantially free from adherent coatings. The presence of a thin, firmly adhering film of weathered rock shall not be considered as coating unless it exists on more than 50 percent of the surface area of any size between successive laboratory sieves.

The portion of aggregate for bituminous surface treatment retained on a U.S. No. 4 sieve shall not contain more than 0.1 percent deleterious materials by weight.

9-03.5 Vacant

9-03.6 Aggregates for Asphalt Treated Base (ATB)

9-03.6(1) General Requirements

Aggregates for asphalt treated base shall be manufactured from ledge rock, talus, or gravel, in accordance with the provisions of Section 3-01, that meet the following test requirements:

Los Angeles Wear, 500 Rev.	30% max.
Degradation Factor	15 min.

9-03.6(2) Grading

Aggregates for asphalt treated base shall meet the following requirements for grading:

Sieve Size	Percent Passing
2″ square	100
½″ square	56-100
U.S. No. 4	32-72
U.S. No. 10	22-57
U.S. No. 40	8-32
U.S. No. 200	2.0-9.0

All percentages are by weight.

9-03.6(3) Test Requirements

When the aggregates are combined within the limits set forth in Section 9-03.6(2) and mixed in the laboratory with the designated grade of asphalt, the mixture shall be capable of meeting the following test values:

% of Theoretical Maximum Specific Gravity (GMM) (approximate)	93@ 100 gyrations
Modified Lottman Stripping Test	Pass

The sand equivalent value of the mineral aggregate for asphalt treated base shall not be less than 35.

9-03.7 Vacant

9-03.8 Aggregates for Hot Mix Asphalt

9-03.8(1) General Requirements

Aggregates for hot mix asphalt shall be manufactured from ledge rock, talus, or gravel, in accordance with the provisions of Section 3-01. The material from which they are produced shall meet the following test requirements:

Los Angeles Wear, 500 Rev.	30% max.
Degradation Factor, Wearing Course	30 min.
Degradation Factor, Other Courses	20 min.

Aggregates shall be uniform in quality, substantially free from wood, roots, bark, extraneous materials, and adherent coatings. The presence of a thin, firmly adhering film of weathered rock will not be considered as coating unless it exists on more than 50 percent of the surface area of any size between consecutive laboratory sieves.

Aggregate removed from deposits contaminated with various types of wood waste shall be washed, processed, selected, or otherwise treated to remove sufficient wood waste so that the oven dried material retained on a U.S. No. 4 sieve shall not contain more than 0.1 percent by weight of material with a specific gravity less than 1.0.

9-03.8(2) HMA Test Requirements

Aggregate for HMA shall meet the following test requirements:

1. Vacant
2. The fracture requirements for the combined coarse aggregate shall apply to the material retained on the U.S. No. 4 sieve and above, when tested in accordance with FOP for AASHTO PT 61.

ESAL's (millions)	# Fractured Faces	% Fracture
< 10	1	90
≥ 10	2	90

3. The uncompacted void content for the combined fine aggregate is tested in accordance with WSDOT Test Method for AASHTO T 304, Method A. The minimum percent voids shall be as required in the following table:

Traffic	HMA Evaluation	
ESAL's (millions)	Statistical & Nonstiatistical	Commercial
< 3	40	40
≥ 3	44	40

4. The minimum sand equivalent for the aggregate shall be 45.

The mix design shall produce HMA mixtures when combined within the limits set forth in Section 9-03.8(6) and mixed in the laboratory with the designated grade of asphalt binder, using the Superpave gyratory compactor in accordance with WSDOT FOP for AASHTO T 312, and at the required gyrations for N initial, N design, and N maximum with the following properties:

	HMA Class							
	3/8-inch		1/2-inch		3/4-inch		1-inch	
Mix Criteria	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**
Voids in Mineral Aggregate (VMA), %	15.0		14.0		13.0		12.0	
Voids Filled with Asphalt (VFA), %								
ESAL's (millions)	VFA							
< 0.3	70	80	70	80	70	80	67	80
0.3 to < 3	65	78	65	78	65	78	65	78
3 to < 10	73	76	65	75	65	75	65	75
10 to < 30	73	76	65	75	65	75	65	75
≥ 30	73	76	65	75	65	75	65	75
Dust/Asphalt Ratio	0.6	1.6	0.6	1.6	0.6	1.6	0.6	1.6
Modified Lottman Stripping Test	Pass		Pass		Pass		Pass	

	ESAL's (millions)	N initial	N design	N maximum
% Gmm	< 0.3	≤ 91.5	96.0	≤ 98.0
	0.3 to < 3	≤ 90.5	96.0	≤ 98.0
	≥ 3	≤ 89.0	96.0	≤ 98.0
Gyratory Compaction (number of gyrations)	< 0.3	6	50	75
	0.3 to < 3	7	75	115
	3 to < 30	8	100	160
	≥ 30	9	125	205

The mix criteria VMA and VFA only apply to HMA accepted by statistical evaluation.

When material is being produced and stockpiled for use on a specific contract or for a future contract, the uncompacted void content, fracture, and sand equivalent requirements shall apply at the time of stockpiling. When material is used from a stockpile that has not been tested as provided above, the specifications for uncompacted void content, fracture, and sand equivalent shall apply at the time of its introduction to the cold feed of the mixing plant.

9-03.8(3) Grading

9-03.8(3)A Gradation

The Contractor may furnish aggregates for use on the same contract from multiple stockpiles. The gradation of the aggregates shall be such that the completed mixture complies in all respects with the pertinent requirements of Section 9-03.8(6).

Acceptance of the aggregate gradation shall be based on samples taken from the final mix.

9-03.8(3)B Gradation — Recycled Asphalt Pavement and Mineral Aggregate

Asphalt concrete planings or old asphalt concrete utilized in the production of HMA shall be sized prior to entering the mixer so that a uniform and thoroughly mixed HMA is produced in the mixer. If there is evidence of the old asphalt concrete not breaking down during the heating and mixing of the HMA, the Engineer may elect to modify the maximum size entering the mixer. No contamination by deleterious materials will be allowed in the old asphalt concrete used.

The gradation for the new aggregate used in the production of the HMA shall be the responsibility of the Contractor, and when combined with recycled material, the combined material shall meet the gradation specification requirements for the specified Class HMA as listed in Section 9-03.8(6) or as shown in the Special Provisions. The new aggregate shall meet the general requirements listed in Section 9-03.8(1) and Section 9-03.8(2).

9-03.8(4) Blending Sand

Blending sand shall be clean, hard, sound material, either naturally occurring sand or crusher fines, and must be material which will readily accept an asphalt coating. The exact grading requirements for the blending sand shall be such that, when it is mixed with an aggregate, the combined product shall meet the requirements of Section 9-03.8(6) for the class of material involved. Blending sand shall meet the following quality requirement:

Sand Equivalent	30 Minimum

9-03.8(5) Mineral Filler

Mineral filler, when used in HMA mix, shall conform to the requirements of AASHTO M 17.

9-03.8(6) HMA Proportions of Materials

The materials of which HMA is composed shall be of such sizes, grading, and quantity that, when proportioned and mixed together, they will produce a well graded mixture within the requirements listed below.

The aggregate percentage refers to completed dry mix, and includes mineral filler when used.

	Aggregate Gradation Control Points			
Sieve Sizes Percent Passing:	**3/8 In.**	**1/2 In.**	**3/4 In.**	**1 In.**
1 1/2" square				100
1" square			100	90-100
3/4" square		100	90-100	90 Maximum
1/2" square	100	90 - 100	90 Maximum	
3/8" square	90 - 100	90 Maximum		
U.S. No. 4	90 Maximum			
U.S. No. 8	32-67	28-58	23-49	19-45
U.S. No. 200	2.0-7.0	2.0-7.0	2.0-7.0	1.0-7.0

9-03.8(7) HMA Tolerances and Adjustments

1. **Job Mix Formula Tolerances.** The constituents of the mixture at the time of acceptance shall conform to the following tolerances:

	Statistical Evaluation	Nonstatistical Evaluation	Commercial Evaluation
Aggregate, percent passing			
1", 3/4", 1/2" and 3/8" sieves	± 6%	± 6%	± 8%
U.S. No. 4 sieve	± 5%	± 6%	± 8%
U.S. No. 8 sieve	± 4%	± 6%	± 8%
U.S. No. 200 sieve	± 2.0%	± 2.0%	± 3.0%
Asphalt binder	± 0.5%	± 0.5%	± 0.7%

VMA	1.5% below minimum value in Section 9-03.8(2)
VFA	minimum and maximum as listed in Section 9-03.8(2)
Va	2.5% minimum and 5.5% maximum

These tolerance limits constitute the allowable limits as described in Section 1-06.2. The tolerance limit for aggregate shall not exceed the limits of the control points, except the tolerance limits for sieves designated as 100% passing will be 99-100. The tolerance limits on sieves shall only apply to sieves with control points. The tolerances for VMA, and Va are for mix design verification and acceptance of the test section. The tolerances for VFA are for mix design verification only. VMA and VFA only apply to HMA accepted by statistical evaluation.

2. Job Mix Formula Adjustments. An adjustment to the aggregate gradation or asphalt binder content of the JMF requires approval of the Project Engineer. Adjustments to the JMF will only be considered if the change produces material of equal or better quality and may require the development of a new mix design if the adjustment exceeds the amounts listed below.
   A. **Aggregates.** The maximum adjustment from the approved mix design shall be 2 percent for the aggregate passing the 1½", 1", ¾", ½", ⅜", and the U.S. No. 4 sieves, 1 percent for aggregate passing the U.S. No. 8 sieve, and 0.5 percent for the aggregate passing the U.S. No. 200 sieve. The adjusted JMF shall be within the range of the control points in Section 9-03.8(6).
   B. **Asphalt Binder Content.** The Project Engineer may order or approve changes to asphalt binder content. The maximum adjustment from the approved mix design for the asphalt binder content shall be 0.3 percent.

9-03.9 Aggregates for Ballast and Crushed Surfacing

9-03.9(1) Ballast

Ballast shall consist of crushed, partially crushed, or naturally occurring granular material from approved sources manufactured in accordance with the provisions of Section 3-01.

The material from which ballast is to be manufactured shall meet the following test requirements:

Los Angeles Wear, 500 Rev	40% max.
Degradation Factor	15 min.

Ballast shall meet the following requirements for grading and quality when placed in hauling vehicles for delivery to the roadway or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

Sieve Size	Percent Passing
2½″ square	100
2″ square	65-100
1″ square	50-85
U.S. No. 4	26-44
U.S. No. 40	16 max.
U.S. No. 200	9.0 max.
Dust Ratio:	⅔ max.
Sand Equivalent	35 min.

All percentages are by weight.

The portion of ballast retained on U.S. No. 4 sieve shall not contain more than 0.2 percent wood waste.

9-03.9(2) Shoulder Ballast

Shoulder ballast shall meet the requirements of Section 9-03.9(1) for ballast except for the following special requirements.

The grading and quality requirements are:

Sieve Size	Percent Passing
2½″ square	100
2″ square	65-100
¾″ square	40-80
U.S. No. 4	5 max.
U.S. No. 100	0-2
% Fracture	75 min.

All percentages are by weight.

The sand equivalent value and dust ratio requirements do not apply.

The fracture requirement shall be at least one fractured face and will apply the combined aggregate retained on the U.S. No. 4 sieve in accordance with FOP for AASHTO PT 61.

9-03.9(3) Crushed Surfacing

Crushed surfacing shall be manufactured from ledge rock, talus, or gravel in accordance with the provisions of Section 3-01. The materials shall be uniform in quality and substantially free from wood, roots, bark, and other extraneous material and shall meet the following quality test requirements:

Los Angeles Wear, 500 Rev.	35% max.
Degradation Factor — Top Course	25 min.
Degradation Factor — Base Course	15 min.

Crushed surfacing of the various classes shall meet the following requirements for grading and quality when placed in hauling vehicles for delivery to the roadway, or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

Sieve Size	Base Course	Top Course and Keystone
	Percent Passing	
1¼″ square	100	
1″ square	80-100	
¾″ square		100
⅝″ square	50-80	
½″ square		80-100
U.S. No. 4	25-45	46-66
U.S. No. 40	3-18	8-24
U.S. No. 200	7.5 max.	10.0 max.
% Fracture	75 min.	75 min.
Sand Equivalent	40 min.	40 min.

All percentages are by weight.

The fracture requirement shall be at least one fractured face and will apply to the combined aggregate retained on the U.S. No. 4 sieve in accordance with FOP for AASHTO PT 61.

The portion of crushed surfacing retained on a U.S. No. 4 sieve shall not contain more than 0.15 percent wood waste.

9-03.9(4) Maintenance Rock

Maintenance rock shall meet all requirements of Section 9-03.9(3) for crushed surfacing top course except that it shall meet the following specifications for grading:

Sieve Size	Percent Passing
⅝″ square	100
½″ square	90-100
U.S. No. 4	45-66
U.S. No. 40	10-25
U.S. No. 200	7 max.

All percentages are by weight.

9-03.10 Aggregate for Gravel Base

Gravel base shall consist of granular material, either naturally occurring or processed. It shall be essentially free from various types of wood waste or other extraneous or objectionable materials. It shall have such characteristics of size and shape that it will compact readily and shall meet the following test requirements:

Stabilometer "R" Value	72 min.
Swell pressure	0.3 psi max.

The maximum particle size shall not exceed ⅔ of the depth of the layer being placed.

Gravel base shall meet the following requirements for grading and quality when placed in hauling vehicles for delivery to the roadway or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

Sieve Size	Percent Passing
2″ square	75-100
U.S. No. 4	22-100
U.S. No. 200	0-10
Dust Ratio:	⅔ max.
Sand Equivalent	30 min.

All percentages are by weight.

Gravel base material retained on a U.S. No. 4 sieve shall contain not more than 0.20 percent by weight of wood waste.

9-03.11 Vacant

9-03.12 Gravel Backfill

Gravel backfill shall consist of crushed, partially crushed, or naturally occurring granular material produced in accordance with the provisions of Section 3-01.

9-03.12(1) Gravel Backfill for Foundations

9-03.12(1)A Class A

Gravel backfill for foundations, Class A, shall conform to the requirements of Section 9-03.9 for ballast or Section 9-03.9(3) for crushed surfacing base course.

9-03.12(1)B Class B

Gravel backfill for foundations, Class B, shall conform to the requirements of Section 9-03.10 except that the requirements for stabilometer "R" value and swell pressure do not apply.

9-03.12(2) Gravel Backfill for Walls

Gravel backfill for walls shall consist of free draining granular material, essentially free from various types of wood waste or other extraneous or objectionable materials. It shall meet the following requirements for grading and quality when placed in hauling vehicles for delivery to the roadway or during manufacture and placement into a temporary stockpile. The exact point of acceptance will be determined by the Engineer.

Sieve Size	Percent Passing
4″ square	100
2″ square	75-100
U.S. No. 4	22-66
U.S. No. 200	5.0 max.
Dust Ratio: $\frac{\text{\% Passing U.S. No. 200}}{\text{\% Passing U.S. No. 40}}$	⅔ max.
Sand Equivalent	60 min.

All percentages are by weight.

That portion of the material retained on a U.S. No. 4 sieve shall contain not more than 0.20 percent by weight of wood waste.

9-03.12(3) Gravel Backfill for Pipe Zone Bedding

Gravel backfill for pipe zone bedding shall consist of crushed, processed, or naturally occurring granular material. It shall be free from various types of wood waste or other extraneous or objectionable materials. It shall have such characteristics of size and shape that it will compact and shall meet the following specifications for grading and quality:

Sieve Size	Percent Passing
1½″ square	100
1″ square	75-100
⅝″ square	50-100
U.S. No. 4	20-80
U.S. No. 40	3-24
U.S. No. 200	10.0 max.
Sand Equivalent	35 min.

All percentages are by weight.

If, in the opinion of the Engineer, the native granular material is free from wood waste, organic material, and other extraneous or objectionable materials, but otherwise does not conform to the specifications for grading and Sand Equivalent, it may be used for pipe bedding for rigid pipes, provided the native granular material has a maximum dimension of 1½-inches.

9-03.12(4) Gravel Backfill for Drains

Gravel backfill for drains shall conform to the following gradings:

Sieve Size	Percent Passing
1″ square	100 - —
¾″ square	80-100
⅜″ square	0-40
U.S. No. 4	0-4
U.S. No. 200	0-2

Alkali silica reactivity testing is not required.

9-03.12(5) Gravel Backfill for Drywells

Gravel backfill for drywells shall conform to the following gradings:

Sieve Size	Percent Passing
1½″ square	100
1″ square	50-100
¾″ square	0-20
⅜″ square	0-2
U.S. No. 200	0-1.5

Alkali silica reactivity testing is not required.

9-03.13 Backfill for Sand Drains

Backfill for sand drains shall conform to the following grading:

Sieve Size	Percent Passing
½″ square	90-100
U.S. No. 4	57-100
U.S. No. 10	40-100
U.S. No. 50	3-30
U.S. No. 100	0-4
U.S. No. 200	0-3.0

All percentages are by weight.

9-03.13(1) Sand Drainage Blanket

Aggregate for the sand drainage blanket shall consist of granular material, free from wood, bark, or other extraneous material and shall meet the following requirements for grading:

Sieve Size	Percent Passing
2½″ square	90-100
U.S. No. 4	24-100
U.S. No. 10	14-100
U.S. No. 50	0-30
U.S. No. 100	0-7.0
U.S. No. 200	0-3.0

All percentages are by weight.

That portion of backfill for sand drains and sand drainage blanket retained on a U.S. No. 4 sieve shall contain not more than 0.05 percent by weight of wood waste.

9-03.14 Borrow

9-03.14(1) Gravel Borrow

Aggregate for gravel borrow shall consist of granular material, either naturally occurring or processed, and shall meet the following requirements for grading and quality:

Sieve Size	Percent Passing
4″ square[1]	100
2″ square	75-100
U.S. No. 4	50-80
U.S. No. 40	30 max.
U.S. No. 200	7.0 max.
Sand Equivalent	50 min.

All percentages are by weight.

[1]For geosynthetic reinforced walls or slopes, 100 percent passing 1¼-inch square sieve and 90 to 100 percent passing 1-inch square sieve.

Ballast may be substituted for gravel borrow for embankment construction.

9-03.14(2) Select Borrow

Material for select borrow shall consist of granular material, either naturally occurring or processed, and shall meet the following requirements for grading and quality:

Sieve Size	Percent Passing
6″ square[1,2]	100
3″ square	75-100
U.S. No. 40	50 max.
U.S. No. 200	10.0 max.
Sand Equivalent	30 min.

All percentages are by weight.

[1]For geosynthetic reinforced walls or slopes, 100 percent passing 1¼-inch square sieve and 90 to 100 percent passing 1-inch square sieve.

[2]100 percent shall pass 4-inch square sieve and 75 to 100 percent shall pass 2-inch square sieve when select borrow is used in the top 2-feet of embankments or where Method C compaction is required.

9-03.14(3) Common Borrow

Material for common borrow shall consist of granular or nongranular soil and/or aggregate which is free of deleterious material and is nonplastic.

Deleterious material includes wood, organic waste, coal, charcoal, or any other extraneous or objectionable material.

The material shall be considered nonplastic if the percent by weight passing the U.S. No. 200 sieve does not exceed 15 percent, or if the soil fraction passing the U.S. No. 40 sieve cannot be rolled, at any moisture content, into a thread as prescribed in Section 4 of AASHTO Test Method T 90. If requested by the Contractor, the plasticity may be increased with the approval of the Engineer if it is determined that an increased plasticity will be satisfactory for the specified embankment construction.

The material shall not contain more than 3 percent organic material by weight.

9-03.14(4) Gravel Borrow for Geosynthetic Retaining Wall

All backfill material used in the reinforced soil zone of the geosynthetic retaining wall shall conform to requirements of Section 9-03.14(1) and shall be free draining, free from organic or otherwise deleterious material. The material shall be substantially free of shale or other soft, poor durability particles, and shall not contain recycled materials, such as glass, shredded tires, portland cement concrete rubble, or asphaltic concrete rubble. The backfill material shall meet the following requirements:

Property	Test Method	Allowable Test Value
Los Angeles Wear, 500 rev.	AASHTO T 96	35 percent max.
Degradation	WSDOT Test Method 113	15 min.
pH	AASHTO T 289-91	**

** 4.5 to 9 for permanent walls and 3 to 10 for temporary walls

Wall backfill material satisfying these gradation, durability and chemical requirements shall be classified as nonaggressive.

9-03.15 Native Material for Trench Backfill

Trench backfill outside the roadway prism shall be excavated material free of wood waste, debris, clods or rocks greater than 6-inches in any dimension.

9-03.16 Vacant

9-03.17 Foundation Material Class A and Class B

Foundation material Class A and Class B shall conform to the following gradations:

	Percent Passing	
Sieve Size	Class A	Class B
2½″ square	98-100	95-100
2″ square	92-100	75-100
1½″ square	72-87	30-60
1¼″ square	58-75	0-15
¾″ square	27-47	0-1
⅜″ square	3-14	---
U.S. No. 4	0-1	---

All percentages are by weight.

9-03.18 Foundation Material Class C

Foundation material Class C shall consist of clean bank run sand and gravel, free from dirt, roots, topsoil, and debris and contain not less than 35 percent retained on a U.S. No. 4 sieve and with all stones larger than 2-inches in the longest dimension removed.

9-03.19 Bank Run Gravel for Trench Backfill

Trench backfill material shall consist of aggregate for gravel base, as specified in Section 9-03.10, excepting however, that 100 percent of the material shall pass a 2½-inch square screen.

9-03.20 Test Methods for Aggregates

The properties enumerated in these Specifications shall be determined in accordance with the following methods of test:

Title	Test Method
Sampling	WSDOT FOP for AASHTO T 2
Organic Impurities	AASHTO T 21
Clay Lumps in Aggregates	AASHTO T 112
Abrasion of Coarse Aggregates by Use of the Los Angeles Machine	AASHTO T 96
Material Finer than U.S. No. 200 Sieve in Aggregates	AASHTO T 11
Percent of Fracture in Aggregates	WSDOT FOP for AASHTO PT 61
Sieve Analysis of Fine and Coarse Aggregates and Aggregates in HMA	WAQTC FOP for T 27/11
Sand Equivalent Test for Surfacing Materials	WSDOT FOP for AASHTO T 176
Determination of Degradation Value	WSDOT T 113
Determination of Fineness Modulus	AASHTO T 27
Particle Size Analysis of Soils	AASHTO T 88
Stabilometer R Value, Untreated Materials	WSDOT T 611
Swell Pressure and Permeability	WSDOT T 611
Stabilometer S Value, Treated Materials	WSDOT T 703
Determining Stripping of HMA	WSDOT T 718
Compressive Strength of Concrete	WSDOT FOP for AASHTO T 22
Flexural Strength of Concrete	WSDOT T 802

9-03.21 Recycled Material

9-03.21(1) General Requirements

Recycled materials that are identified below may be used as, or blended uniformly with, naturally occurring materials for aggregates. The final blended product shall meet the requirements for the specified type of aggregate. In addition, each recycled material component included in a blended product, shall meet the specific requirements listed below.

Recycled materials obtained from the Contracting Agency's roadways will not require testing and certification for toxicity testing or certification for toxicity characteristics.

For recycled materials that are imported to the job site, the Contractor shall certify that the recycled material is not a Washington State Dangerous Waste per the Dangerous Waste Regulations WAC 173-303. Sampling and testing for toxicity shall be at a frequency of one per 10,000 tons prior to combining with other materials and not less than one sample from any single source.

9-03.21(2) Recycled Hot Mix Asphalt

Recycled asphalt concrete pavement may be uniformly blended with the following materials, to the extent that the specified maximum bitumen content in the final product shall not exceed the following:

		Maximum Bitumen Content (Percent)
Fine Aggregate for Portland Cement Concrete	9-03.1(2)	0
Coarse Aggregates for Portland Cement Concrete	9-03.1(4)	0
Aggregates for Asphalt Treated Base (ATB)	9-03.6	See 5-04.2
Aggregates for Hot Mix Asphalt	9-03.8	See 5-04.2
Ballast	9-03.9(1)	1.2
Shoulder Ballast	9-03.9(2)	1.2
Crushed Surfacing	9-03.9(3)	1.2
Aggregate for Gravel Base	9-03.10	1.2
Gravel Backfill for Foundations – Class A	9-03.12(1)A	1.2
Gravel Backfill for Foundations – Class B	9-03.12(1)B	1.2
Gravel Backfill for Walls	9-03.12(2)	0
Gravel Backfill for Pipe Zone Bedding	9-03.12(3)	0
Gravel Backfill for Drains	9-03.12(4)	0
Gravel Backfill for Drywells	9-03.12(5)	0
Backfill for Sand Drains	9-03.13	0
Sand Drainage Blanket	9-03.13(1)	0
Gravel Borrow	9-03.14(1)	1.2
Select Borrow	9-03.14(2)	1.2
Select Borrow (greater than 3-feet below subgrade and side slopes)	9-03.14(2)	8.0
Common Borrow	9-03.14(3)	1.2
Common Borrow - (greater than 3-feet below subgrade and side slopes)	9-03.14(3)	8.0
Foundation Material Class A and Class B	9-03.17	0
Foundation Material Class C	9-03.18	0
Bank Run Gravel for Trench Backfill	9-03.19	0

The following field operating procedures will determine total bitumen content:

AASHTO T 308

WSDOT TM 6

The Contractor shall verify the asphalt content for the blended mix. A statewide average of 0.70 may be used as a calibration factor for AASHTO T-308.

9-03.21(3) Recycled Portland Cement Concrete Rubble

Recycled portland cement concrete rubble may be uniformly blended with the following materials, to the extent that the specified maximum concrete rubble content in the final product shall not exceed the following:

		Maximum Concrete Rubble (Percent)
Fine Aggregate for Portland Cement Concrete	9-03.1(2)	0
Coarse Aggregates for Portland Cement Concrete	9-03.1(4)	0
Aggregates for Asphalt Treated Base (ATB)	9-03.6	0
Aggregates for Hot Mix Asphalt	9-03.8	0
Ballast	9-03.9(1)	100
Shoulder Ballast	9-03.9(2)	100
Crushed Surfacing	9-03.9(3)	100
Aggregate for Gravel Base	9-03.10	100
Gravel Backfill for Foundations – Class A	9-03.12(1)A	100
Gravel Backfill for Foundations – Class B	9-03.12(1)B	100
Gravel Backfill for Walls	9-03.12(2)	100
Gravel Backfill for Pipe Zone Bedding	9-03.12(3)	100
Gravel Backfill for Drains	9-03.12(4)	100
Gravel Backfill for Drywells	9-03.12(5)	0
Backfill for Sand Drains	9-03.13	100
Sand Drainage Blanket	9-03.13(1)	100
Gravel Borrow	9-03.14(1)	100
Select Borrow	9-03.14(2)	100
Common Borrow	9-03.14(3)	100
Foundation Material Class A and Class B	9-03.17	100
Foundation Material Class C	9-03.18	100
Bank Run Gravel for Trench Backfill	9-03.19	100

9-03.21(4) Recycled Glass Aggregates

Recycled glass may be uniformly blended with the following materials, to the extent that the maximum recycled glass content in the final product shall not exceed the following:

		Maximum Recycled Glass (Percent)
Fine Aggregate for Portland Cement Concrete	9-03.1(2)	0
Coarse Aggregates for Portland Cement Concrete	9-03.1(4)	0
Aggregates for Asphalt Treated Base (ATB)	9-03.6	0
Aggregates for Hot Mix Asphalt	9-03.8	0
Ballast	9-03.9(1)	15
Shoulder Ballast	9-03.9(2)	15
Crushed Surfacing	9-03.9(3)	15
Aggregate for Gravel Base	9-03.10	15
Gravel Backfill for Foundations – Class A	9-03.12(1)A	15
Gravel Backfill for Foundations – Class B	9-03.12(1)B	15
Gravel Backfill for Walls	9-03.12(2)	15
Gravel Backfill for Pipe Zone Bedding	9-03.12(3)	15
Gravel Backfill for Drains	9-03.12(4)	100
Gravel Backfill for Drywells	9-03.12(5)	100
Backfill for Sand Drains	9-03.13	100
Sand Drainage Blanket	9-03.13(1)	100
Gravel Borrow	9-03.14(1)	100
Select Borrow	9-03.14(2)	100
Common Borrow	9-03.14(3)	100
Foundation Material Class A and Class B	9-03.17	100
Foundation Material Class C	9-03.18	100
Bank Run Gravel for Trench Backfill	9-03.19	100

The product supplier shall perform total lead content testing quarterly. Tests shall include a minimum of five samples. Sample collection shall be conducted according to ASTM D 75. Total lead content testing will be conducted according to EPA Method 3010/6010.

A test shall not exceed 250 ppm using a total lead analysis EPA Test Method 6010. In addition, the Toxicity Characteristics Leaching Procedure, EPA Test Method 1311 shall be used and a test shall not exceed 5.0 ppm. The product supplier shall keep all test results on file.

9-03.21(5) Steel Furnace Slag

Steel furnace slag may be uniformly blended with the following materials, to the extent that the specified maximum steel furnace slag content in the final product shall not exceed the following:

		Maximum Steel Furnace Slag (Percent)
Fine Aggregate for Portland Cement Concrete	9-03.1(2)	0
Coarse Aggregates for Portland Cement Concrete	9-03.1(4)	0
Aggregates for Asphalt Treated Base (ATB)	9-03.6	20
Aggregates for Hot Mix Asphalt	9-03.8	20
Ballast	9-03.9(1)	20
Shoulder Ballast	9-03.9(2)	20
Crushed Surfacing	9-03.9(3)	20
Aggregate for Gravel Base	9-03.10	20
Gravel Backfill for Foundations – Class A	9-03.12(1)A	20
Gravel Backfill for Foundations – Class B	9-03.12(1)B	20
Gravel Backfill for Walls	9-03.12(2)	20
Gravel Backfill for Pipe Zone Bedding	9-03.12(3)	20
Gravel Backfill for Drains	9-03.12(4)	0
Gravel Backfill for Drywells	9-03.12(5)	0
Backfill for Sand Drains	9-03.13	0
Sand Drainage Blanket	9-03.13(1)	0
Gravel Borrow	9-03.14(1)	20
Select Borrow	9-03.14(2)	20
Select Borrow (greater than 3-feet below subgrade and side slopes)	9-03.14(2)	20
Common Borrow	9-03.14(3)	20
Common Borrow (greater than 3-feet below subgrade and side slopes)	9-03.14(3)	20
Foundation Material Class A and Class B	9-03.17	20
Foundation Material Class C	9-03.18	20
Bank Run Gravel for Trench Backfill	9-03.19	20

The Contractor shall notify the Engineer the proposed steel furnace slag blends that will be used in the final product prior to use.

9-04 JOINT AND CRACK SEALING MATERIALS

9-04.1 Premolded Joint Fillers

9-04.1(1) Asphalt Filler for Contraction and Longitudinal Joints in Concrete Pavements

Premolded joint filler for use in contraction and longitudinal joints shall be ⅛-inch in thickness and shall consist of a suitable asphalt mastic encased in asphalt saturated paper or asphalt saturated felt. It shall be sufficiently rigid for easy installation in summer months and not too brittle for handling in cool weather. It shall meet the following test requirements:

When a strip 2-inches wide and 24-inches long is freely supported 2-inches from each end and maintained at a temperature of 70 F, it shall support a weight of 100 grams placed at the center of the strip without deflecting downward from a horizontal position more than 2-inches within a period of 5 minutes.

9-04.1(2) Premolded Joint Filler for Expansion Joints

Premolded joint filler for use in expansion (through) joints shall conform to the specifications for "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction," AASHTO M 213, except the requirement for water absorption which is deleted.

9-04.1(3) Vacant

9-04.1(4) Elastomeric Expansion Joint Seals

Premolded elastomeric expansion joint seals shall conform to the requirements of AASHTO M 220 and shall be formed by an extrusion process with uniform dimensions and smooth exterior surfaces. The cross-section of the seal shall be shaped to allow adequate compressed width of the seal, as approved by the Engineer.

9-04.2 Joint Sealants

9-04.2(1) Hot Poured Joint Sealants

Hot poured joint sealants shall meet the requirements of AASHTO M 173 Concrete Joint Sealer, Hot Poured Elastic Type and be sampled in accordance with ASTM D 5167. In addition, the sealant shall have a C.O.C. Flash Point (AASHTO T 48) of 205°C minimum. In lieu of the specified bond test in M 173, the bond test shall be in accordance with WSDOT Test Method 412.

9-04.2(2) Poured Rubber Joint Sealer

The physical properties of the joint sealer, when mixed in accordance with the manufacturer's recommendations, shall be as follows:

1. Color: Gray or black.
2.[1] Viscosity: Must be pourable and self-leveling at 50ºF.
3.[1] Application Life: Not less than 3 hours at 72ºF and 50 percent relative humidity.
4. Set to Touch: Not more than 24 hours at 72ºF and 50 percent relative humidity.
5. Curing Time: Not more than 96 hours at 72ºF and 50 percent relative humidity.
6. NonVolatile Content: Not less than 92 percent.
7. Hardness Rating (Durometer "Shore A"): 5-35.
8. Resiliency: Not less than 80 percent.

9. Bond test methods shall be in accordance with WSDOT Test Method No. 412.

[1]Viscosity and application life may be waived providing the material is mixed and placed by a pump and mixer approved by the Engineer.

Suitable primer, if required by the manufacturer, shall be furnished with each joint sealer. The primer shall be suitable for brush or spray application at 50ºF or higher and shall cure sufficiently at 50ºF to pour the joint within 24 hours. It shall be considered as an integral part of the sealer system. Any failure of the sealer in the test described herein, attributable to the primer, shall be grounds for rejection or re-testing of the sealer.

Acceptance of joint sealing compound for use on a project shall be on the basis of laboratory tests of samples representative of each batch of material to be used on the job. A period of at least two weeks shall be allowed for completion of tests. Each container of the compound shall be clearly identified as to batch number.

9-04.3 Joint Mortar

Mortar for hand mortared joints shall consist of one part Portland cement, three parts fine sand, and sufficient water to allow proper workability.

Cement shall conform to the requirements of AASHTO M 85, Type I or Type II.

Sand shall conform to the requirements of AASHTO M 45.

Water shall conform to the requirements of Section 9-25.1.

9-04.4 Pipe Joint Gaskets

9-04.4(1) Rubber Gaskets for Concrete Pipes and Precast Manholes

Rubber gaskets for use in joints of concrete culvert or storm sewer pipe and precast manhole sections shall conform to the applicable requirements of AASHTO M 198.

9-04.4(2) Vacant

9-04.4(3) Gaskets for Aluminum or Steel Culvert or Storm Sewer Pipe

Rubber gaskets for use with metal culvert or storm sewer pipe shall be continuous closed cell, synthetic expanded rubber gaskets conforming to the requirements of ASTM D 1056, Grade 2B3. Butyl rubber gaskets for use with metal culvert or storm sewer pipe shall conform to the applicable requirements of AASHTO M 198.

9-04.4(4) Rubber Gaskets for Aluminum or Steel Drain Pipe

Gaskets for metal drain pipe shall be self-adhering, butyl-based, scrim-supported type. The gaskets shall be as described in the Standard Plan when specified.

9-04.4(5) Protection and Storage

Rubber gasket material shall be stored in a clean, cool place, protected from sunlight and contaminants. They shall be protected from direct sunlight at all times except during actual installation. Pipes with gaskets affixed shall be installed in the line within 28 days.

9-04.5 Flexible Plastic Gaskets

The gasket material shall be produced from blends of refined hydrocarbon resins and plasticizing materials reinforced with inert mineral filler and shall contain no solvents. It shall not depend on oxidizing, evaporating, or chemical action for adhesive or cohesive strength. It shall be supplied in extruded rope form of such cross section and size as to adequately fill spaces between the precast sections.

The gasket material shall be protected by a suitable removable two-piece wrapper so designed as to permit removing one half, longitudinally, without disturbing the other. Its composition and properties shall conform to those set forth below.

	Test Method	Minimum	Maximum
Bitumen (Petroleum plastic content)	ASTM D 4	50	70
Ash-inert Mineral Matter	AASHTO T 11	30	50
Penetration	ASTM D 217		
32ºF (300gm) 60 sec		75	---
77ºF (150gm) 5 sec		50	120
115ºF (150gm) 5 sec		---	150
Softening Point	AASHTO T 53	320ºF	---
Specific Gravity at 77ºF	AASHTO T 229	1.20	1.35
Weight per gallon, lb.		10.0	11.3
Ductility at 77ºF (cm)	ASTM D 113	5.0	---
Flash Point COC, F	AASHTO T 73	600	---
Fire Point COC, F	AASHTO T 48	625	---
Volatile Matter	AASHTO T 47	---	2.0

9-04.6 Expanded Polystyrene

Expanded polystyrene shall be of a cellular molded type with a density of 1.5 plus or minus 0.25 pounds per cubic foot.

9-04.7 Expanded Rubber

Closed cell expanded rubber joint filler shall conform to ASTM D 1056, Grade No. 2B3.

9-04.8 Flexible Elastomeric Seals

Flexible elastomeric seals for PVC drain pipe and underdrain pipe shall conform to the requirements of ASTM D 3212.

9-04.9 Solvent Cements

Solvent cements for PVC underdrain pipe shall conform to the requirements of ASTM D 2564.

9-04.10 Crack Sealing — Rubberized Asphalt

Crack sealing material shall meet the requirements of Section 9-04.2(1), except no bond test is required.

9-04.11 Butyl Rubber

Butyl rubber shall conform to ASTM D 2000, M1 BG 610. If the Engineer determines that the butyl rubber is utilized in an area that will not be exposed to petroleum products, it shall conform to ASTM D 2000, M1 BA 610.

9-05 DRAINAGE STRUCTURES, CULVERTS, AND CONDUITS

9-05.0 Acceptance by Manufacturer's Certification

Certain drainage materials may be accepted by the Engineer based on a modified acceptance procedure when materials are furnished from the manufacturer's list in the Qualified Products List (QPL) or by a Manufacturer's Certificate of Compliance. The modified acceptance procedure is defined in the QPL for each material. These materials are as follows:

Metal drain and under drain pipe;

PVC and corrugated polyethylene drain pipe and under drain pipe;

Metal culvert and storm sewer pipe and pipe arch;

Metal culvert end sections;

Corrugated metal structural plate pipe, pipe arch, and under passes; and

Ductile iron pipe.

Corrugated polyethylene culvert and storm sewer pipe up to and including 60-inch diameter.

Profile wall PVC culvert and storm sewer pipe up to and including 48-inch diameter.

9-05.1 Drain Pipe

9-05.1(1) Concrete Drain Pipe

Concrete drain pipe shall meet the requirements of ASTM C 118M, heavy duty drainage pipe.

9-05.1(2) Zinc Coated (Galvanized) or Aluminum Coated (Aluminized) Corrugated Iron or Steel Drain Pipe

Zinc coated (galvanized) or aluminum coated (aluminized Type 2) corrugated iron or steel drain pipe shall meet the requirements of AASHTO M 36. The steel sheet thickness shall be 0.064-inch for 6-inch diameter and larger drain pipe. Zinc coated steel shall meet the material requirements of AASHTO M 218 (ASTM A929). Aluminum coated steel shall meet the material requirements of AASHTO M-274 (ASTM A929).

9-05.1(2)A Coupling Bands

Coupling bands for zinc coated (galvanized) or aluminum coated (aluminized) corrugated iron or steel drain pipe shall meet the requirements of coupling bands for Type I pipe of AASHTO M 36, except that bands using projections (dimples) shall not be permitted. The bands shall be fabricated of the same material as the pipe, and with the same metallic protective treatment as the pipe.

Acceptable coupling bands are the two piece helically corrugated band with nonreformed ends and integrally formed flanges and those bands meeting the requirements of Section 9-05.4(7).

9-05.1(3) Corrugated Aluminum Alloy Drain Pipe

Corrugated aluminum alloy drain pipe shall meet the requirements of AASHTO M 196, without perforations.

9-05.1(3)A Coupling Bands

Coupling bands for corrugated aluminum alloy drain pipe shall meet the requirements of coupling bands for Type I pipe of AASHTO M 196, except that bands using projections (dimples) shall not be permitted. The bands shall be fabricated of the same material as the pipe.

Acceptable coupling bands are the two piece helically corrugated band with nonreformed ends and integrally formed flanges and those bands meeting the requirements of Section 9-05.5(5).

9-05.1(4) Vacant

9-05.1(5) PVC Drain Pipe

PVC drain pipe shall meet the requirements of AASHTO M 278. The maximum size pipe shall be 8-inches in diameter.

9-05.1(6) Corrugated Polyethylene Drainage Tubing Drain Pipe

Corrugated polyethylene drainage tubing drain pipe shall meet the requirements of AASHTO M 252. The maximum size pipe shall be 10-inches in diameter.

9-05.1(7) Corrugated Polyethylene Drain Pipe

Corrugated polyethylene drain pipe, 12-inch through 36-inch diameter maximum, shall meet the minimum requirements of AASHTO M 294 Type S.

9-05.2 Underdrain Pipe

9-05.2(1) Vacant

9-05.2(2) Perforated Concrete Underdrain Pipe

Perforated concrete underdrain pipe shall meet the requirements of AASHTO M 175, Type I, except the perforations shall be approximately ½-inch in diameter. Strength requirements shall be as shown in Table I of AASHTO M 86.

9-05.2(3) Perforated Bituminized Fiber Underdrain Pipe

Perforated bituminized fiber underdrain pipe shall meet the requirements of AASHTO M 177.

9-05.2(4) Zinc Coated (Galvanized) or Aluminum Coated (Aluminized) Corrugated Iron or Steel Underdrain Pipe

Zinc coated (galvanized) or aluminum coated (aluminized type 2) corrugated iron or steel underdrain pipe shall meet the fabrication requirements of AASHTO M 36, except that perforations required in Class I, II, and III pipe may be located anywhere on the tangent of the corrugations provided the other perforation spacing requirements remain as specified. Zinc coated steel shall meet the material requirements of AASHTO M 218 (ASTM A929). Aluminum coated steel shall meet the material requirements of AASHTO M-274 (ASTM A929).

The pipe may conform to any one of the Type III pipes specified in AASHTO M 36, and perforations in Class I, II, and III pipe may be drilled or punched. The sheet thickness shall be 0.064-inch for 6-inch and larger diameter underdrain pipe.

9-05.2(4)A Coupling Bands

Coupling bands for zinc coated (galvanized) or aluminum coated (aluminized) corrugated iron or steel underdrain pipe shall meet the requirements of coupling bands for Type III pipe of AASHTO M 36. The bands shall be fabricated of the same material as the pipe and with the same metallic protective treatment as the pipe, if metallic bands are used.

Acceptable coupling bands are the two piece helically corrugated band with nonreformed ends and integrally formed flanges, universal bands (dimple bands), a smooth sleeve type coupler, and those bands meeting the requirements of Section 9-05.4(7). Smooth sleeve type couplers may be either plastic or steel suitable for holding the pipe firmly in alignment without the use of sealing compound or gaskets.

9-05.2(5) Perforated Corrugated Aluminum Alloy Underdrain Pipe

Perforated corrugated aluminum alloy underdrain pipe shall meet the requirements of AASHTO M 196, except that the perforations may be located anywhere on the tangent of the corrugations providing the other perforation spacing requirements remain as specified.

9-05.2(5)A Coupling Bands

Coupling bands for corrugated aluminum alloy underdrain pipe shall meet the requirements of coupling bands for Type III pipe of AASHTO M 196. The bands shall be fabricated of the same material of the pipe, if metallic bands are used.

Acceptable coupling bands are the two piece helically corrugated band with nonreformed ends and integrally formed flanges, universal bands (dimple bands), a smooth sleeve type coupler, and those bands meeting the requirements of Section 9-05.5(5). Smooth sleeve type couplers may be either plastic or aluminum alloy suitable for holding the pipe firmly in alignment without the use of sealing compound or gaskets.

9-05.2(6) Perforated PVC Underdrain Pipe

Perforated PVC underdrain pipe shall meet the requirements of AASHTO M 278. The maximum size pipe shall be 8-inches in diameter.

9-05.2(7) Perforated Corrugated Polyethylene Drainage Tubing Underdrain Pipe

Perforated corrugated polyethylene drainage tubing underdrain pipe shall meet the requirements of AASHTO M252, Type CP or Type SP. Type CP shall be Type C pipe with Class 2 perforations and Type SP shall be Type S pipe with either Class 1 or Class 2 perforations. Additionally, Class 2 perforations shall be uniformly spaced along the length and circumference of the pipe. The maximum size pipe shall be 10-inch diameter.

9-05.2(8) Perforated Corrugated Polyethylene Underdrain Pipe

Perforated corrugated polyethylene underdrain pipe, 12-inch through 48-inch diameter maximum, shall meet the requirements of AASHTO M 294 Type CP or Type SP. Type CP shall be Type C pipe with Class 2 perforations and Type SP shall be Type S pipe with either Class 1 or Class 2 perforations. Additionally, Class 2 perforations shall be uniformly spaced along the length and circumference of the pipe.

9-05.3 Concrete Culvert Pipe

9-05.3(1) Plain Concrete Culvert Pipe

Plain concrete culvert pipe shall be round and shall conform to the requirements of AASHTO M 86, Class 2.

9-05.3(1)A End Design and Joints

All bell and spigot concrete culvert pipe shall be joined with rubber gaskets. The joints and gasket material shall meet the requirements of AASHTO M 198. Gasket material shall be handled and stored in accordance with Section 9-04.4(5).

The plans of the ends of the pipes shall be perpendicular to their longitudinal axes.

9-05.3(1)B Basis for Acceptance

The basis for acceptance of plain concrete culvert or drain pipe shall be on the results of three edge bearing tests performed at the manufacturer's plant within the 90 day period immediately preceding shipment of the pipe.

9-05.3(1)C Age at Shipment

Plain concrete culvert pipe may be shipped when it meets all test requirements. Unless it is tested and accepted at an earlier age, it shall not be considered ready for shipment sooner than 28 days after manufacture when made with Type II Portland cement, nor sooner than 7 days when made with Type III Portland cement.

9-05.3(2) Reinforced Concrete Culvert Pipe

Reinforced concrete culvert pipe shall be round and conform to the requirements of AASHTO M 170 except as herein provided.

The wall thickness and steel area for all classes of pipe which are of a diameter not set forth in AASHTO M 170, but within the maximum and minimum diameter limits set forth therein, shall be determined by interpolation from data given in the tables for pipes of diameters next smaller and next larger, respectively.

For all classes of pipe, except Class I, which are of a diameter less than the minimum for the particular class set forth in AASHTO M 170, the minimum wall thickness shall be 1¾-inch and the steel area shall not be less than 0.06 square inch per linear foot of pipe barrel length.

9-05.3(2)A End Design and Joints

Section 9-05.3(1)A will apply to reinforced concrete culvert pipe.

9-05.3(2)B Basis for Acceptance

The basis for acceptance of reinforced concrete pipe 60-inches in diameter and smaller shall be determined by the results of the three edge bearing test for the load to produce a 0.01-inch crack, and testing to the ultimate load will ordinarily not be required, except as necessary to obtain samples for making the absorption test. In lieu of broken pieces of pipe obtained as above provided, 4-inch diameter cores from pipe sections selected by the Engineer may be furnished for performing the absorption test. Sections of pipe which have been tested to the actual 0.01-inch crack will ordinarily not be further load tested; and such sections which meet or exceed the required strength and workmanship standards may be accepted for use on the project.

Acceptance of reinforced concrete pipe larger than 60-inches in diameter shall be based on inspection of the size and placement of the reinforcing steel, and, at the option of the Engineer, on compressive strength tests of 4-inch diameter cores cut from the pipe, or on compressive strength of representative test cylinders cast with and cured with the pipe.

9-05.3(2)C Age at Shipment

Reinforced concrete culvert pipe may be shipped when it meets the requirements of Section 9-05.3(1)C.

9-05.3(2)D Elliptical Reinforcement

In lieu of marking circular pipe with elliptical reinforcement in accordance with AASHTO M 170, the location of the top of the pipe shall be indicated by 3-inch, waterproof, painted stripes on the inside and outside of the pipe for a distance of 2-feet from each end of the section. At the option of the Contractor, a lift hole or lift holes may be provided at the top of the pipe in lieu of the painted stripes. If one lift hole is provided, it shall be at the balance point of the pipe; and if two lift holes are provided, they shall be spaced equidistant each side of the balance point. Such holes shall not interfere with the reinforcement. After placing, open lift holes shall be filled with mortar or concrete plugs before backfilling.

In addition to the requirements as set forth in AASHTO M 170, it will be required on all pipe 30-inches and over in diameter with elliptical steel reinforcement that the manufacturer expose the reinforcement in not less than one of three lengths of pipe manufactured. A hole exposing the steel shall be cut on the inside of the pipe at top or bottom and a second hole on the outside, 90 degrees from the top or bottom position. After placing, holes exposing the reinforcement shall be filled with mortar or concrete plugs before backfilling.

9-05.3(3) Beveled Concrete End Sections

Beveled concrete end sections shall be plain concrete conforming to AASHTO M 86 or reinforced concrete conforming to the applicable sections of AASHTO M 170 with the design requirements as listed in Table 2, Wall B, Circular Reinforcement in circular pipe, and the Standard Plan.

9-05.4 Steel Culvert Pipe and Pipe Arch

Steel culvert pipe and pipe arch shall meet the fabrication requirements of AASHTO M 36, Type I and Type II. . Zinc coated steel shall meet the material requirements of AASHTO M 218 (ASTM A929). Aluminum coated steel shall meet the material requirements of AASHTO M-274 (ASTM A929).

9-05.4(1) Elliptical Fabrication

When elongated pipes are specified, circular pipes shall be fabricated 5 percent out of round to form an elliptical section. The vertical or longer axis of the elliptical section shall be clearly marked before shipping.

9-05.4(2) Mitered Ends

The ends of steel culvert pipe or pipe arch shall not be beveled unless called for in the plans. If beveled ends are specified, the ends of culvert pipe over 30-inches in diameter shall be mitered to conform to the slope of the embankment in which the culvert is to be placed whether the culvert is constructed normal to or at an angle with the centerline of the roadway.

Beveled steel pipe end sections 12-inches through 30-inches in diameter shall be of the same material and thickness and have the same protective coating as the pipe to which they are attached. Beveled pipe ends of these dimensions shall be constructed in conformance with the Standard Plan.

9-05.4(3) Protective Treatment

Steel pipe and pipe arch culverts shall be coated by one of the following protective treatments, when such treatment is specified:

Treatment 1	Coated uniformly inside and out with asphalt as per 9-05.4(4) (AASHTO M190 Type A) or with polymer as per 9-05.4(6).
Treatment 2	Coated uniformly inside and out with asphalt and with an asphalt paved invert (AASHTO M 190 Type C) or with polymer as per 9-05.4(6).
Treatment 3	This treatment is no longer available.
Treatment 4	This treatment is no longer available.
Treatment 5	Coated inside and out with asphalt and a 100 percent periphery inside spun asphalt lining (AASHTO M 190 Type D).
Treatment 6	This treatment is no longer available.

9-05.4(4) Asphalt Coatings and Paved Inverts

Asphalt for asphalt coatings and paved inverts shall meet the requirements of AASHTO M 190, Section 4. The coatings for Treatments 1, 2, and 5 shall be uniform, inside and out, and applied in accordance with the following requirements:

The metal shall be free from grease, dirt, dust, moisture, or other deleterious contaminants. Either process described below may be used for application.

1. **Pipe Not Preheated**. The temperature of the asphalt at the time of pipe immersion shall be 400ºF (plus or minus 3 degrees), and the duration of the immersion shall conform to the following schedule:

Thickness in inches Steel	Minimum Immersion Time Minutes
0.064	2.5
0.079	3.0
0.109	5.0
0.138	6.5
0.168	8.0

2. Pipe Preheated. The asphalt shall have a temperature of 380ºF (plus or minus 3 degrees), and the pipe shall be brought to a temperature of 300ºF to 350ºF before immersion.

   The paved invert for Treatment 2 shall consist of bituminous material applied in such a manner that one or more smooth pavements will be formed in the invert filling the corrugations for at least 40 percent of the circumference. The pavement shall have a minimum thickness of $^{1}/_{8}$-inch above the crest of

the corrugations except where the upper edges intercept the corrugation. The pavements shall be applied following the coating with asphalt . Treatment 5 may be substituted for Treatment 2, at the option of the Contractor.

9-05.4(5) Polymer Protective Coating

Polymer coated steel pipe and pipe-arch shall meet the fabrication requirements of AASHTO M 36 (ASTM A760). Polymer protective coatings shall meet the material requirements of AASHTO M 246 (ASTM A742). Polymer coating shall be mill applied to galvanized steel coils before fabrication and shall measure 10 mils thick on each side.

9-05.4(6) Spun Asphalt Lining

Asphalt for spun linings over 100 percent periphery shall conform to AASHTO M 190, Section 4. Asphalt spun linings shall provide a smooth surface for the full interior of the pipe by completely filling the corrugations to a minimum thickness of ⅛-inch above the crests. The interior lining shall be applied by centrifugal or other approved methods. The interior shall be free from sags or runs, but slight residual corrugations due to cooling shrinkage of the lining will not be cause for rejection. At the three sheet laps, an interior nonuniformity equal to the thickness of the sheet is allowable. The thickness of the lining shall be maintained to the ends of the pipe.

The thickness of the lining over the crest of the corrugation shall not vary by an amount in excess of ½-inch over the entire area of the spun lining.

In the case of helical corrugated pipe manufactured with a continuous lock seam, an interior nonuniformity over the lock seam equal to the thickness of two culvert sheets is allowable.

9-05.4(7) Coupling Bands

Coupling bands for steel pipe shall be as shown in the Standard Plans and shall be fabricated of the same material as the pipe. Bands may be up to three nominal thicknesses thinner than used for the pipe, but not thinner than 0.064-inches or thicker than 0.109-inches. Bands shall be coated with the same metallic protective treatment as the pipe but shall not be coated with any asphalt protective treatment. Bands shall be made by the same manufacturer as the steel pipe selected for installation.

Corrugations on the bands shall be the same size and shape as those on the pipes to be connected. Steel bolts and nuts for coupling bands shall meet the requirements of ASTM A 307 and shall be galvanized in accordance with AASHTO M 232. Steel angles, when required for coupling bands, shall meet the requirements of AASHTO M 36. When annular corrugated bands are used to connect helically corrugated lock-seam pipe, the seam shall be welded at the pipe ends prior to recorrugating to prevent unraveling of the seam. All welds shall develop the full strength of the parent metal.

Bands shall conform to the corrugations of the pipe and shall meet all applicable requirements of AASHTO M 36, with the following exceptions:

Coupling bands for all sizes of steel pipe arch with 3-inch by 1-inch corrugations shall be 24-inches wide.

Type K coupling bands shall only be used on circular culvert pipe when extending an existing culvert. Rubber gaskets shall be used and shall conform to the requirements of Section 9-04.4(3), match the width of the band, and have a minimum thickness of 1-inch.

Type K coupling bands are allowed for use on all sizes of steel pipe arch with 3-inch by 1-inch corrugations. Type K bands for this application shall be 24-inches wide. Rubber gaskets shall be used and shall conform to the requirements of Section 9-04.4(3), match the width of the band, and have a minimum thickness of 1-inch. When Type K bands are used, pipe arch ends are not required to be recorrugated.

Gaskets are required for all culvert installations and shall meet the requirements of 9-05.10(1).

9-05.4(8) Steel Nestable Pipe

Steel nestable pipe shall meet the requirements for steel pipe of these Specifications except in the method of fabrication. Circular pipe shall be fabricated in two semicircles.

Nestable pipe may be either the stitch-type as hereinafter described or the flange-type in accordance with Military Designation MIL-P-236. One longitudinal edge of each half of the stitch-type nestable circular pipe shall be notched to provide interlocking seams which will form the two segments into the full section when it is erected in the field. Hook and eye bolts, or other approved means, shall be provided to hold the segments firmly together.

Individual plates shall be a minimum of 2-feet in length except for short or half sections required to complete the end section of the culvert.

When protective treatment is specified in the Plans, nestable pipe shall be coated with one of the treatments as provided in Section 9-05.4(3).

9-05.4(9) Steel End Sections

The applicable provisions of AASHTO M 36 shall apply to the construction of steel end sections, except that the end sections shall be fabricated of the same material with the same metallic protective treatment as the pipe.

Asphalt coating shall not be used on steel end sections.

9-05.4(9)A Fabrication

The shape, thickness, dimensions, and number of pieces shall conform to the Standard Plan for the size and shape of pipe shown in the Plans. They shall be manufactured as integral units or so formed that they can be readily assembled and erected in place. When bolts are used for assembly, they shall be ⅜-inch diameter or larger and shall be galvanized. No field welding or riveting will be permitted.

9-05.4(9)B Galvanized Hardware

Bolts, nuts, and miscellaneous hardware shall be galvanized in accordance with the provisions of AASHTO M 232.

9-05.4(9)C Toe Plate Extensions

Toe plate extensions shall be furnished only when so designated in the Plans. When required, the toe plate extensions shall be punched with holes to match those in the lip of the skirt and fastened with ⅜-inch or larger galvanized nuts and bolts. Toe plate extensions shall be the same material and thickness as the end section and shall be fabricated of the same material with the same metallic protective treatment as the end section.

9-05.5 Aluminum Culvert Pipe

Aluminum culvert pipe shall conform to the applicable requirements of AASHTO M 196M.

9-05.5(1) Elliptical Fabrication

Section 9-05.4(1) shall apply to aluminum pipes.

9-05.5(2) Mitered Ends

Section 9-05.4(2) shall apply to aluminum pipes.

9-05.5(3) Vacant

9-05.5(4) Vacant

9-05.5(5) Coupling Bands

Bands shall be fabricated of the same material as the pipe and shall meet all applicable requirements of AASHTO M 196, except the band thickness shall not be more than 0.105-inches or less than 0.060-inches. All other requirements of Section 9-05.4(7) shall apply.

9-05.5(6) Aluminum End Sections

The applicable provisions of AASHTO M 196 shall apply to the construction of end sections and toe plate extensions for aluminum pipes. In addition, they shall conform to the requirements of Section 9-05.4(9).

Asphalt coating shall not be used on aluminum end sections.

9-05.6 Structural Plate Pipe, Pipe Arch, Arch, and Underpass

9-05.6(1) General

Structural plate pipes shall be full circle of the type, gage or thickness, and diameter specified.

Structural plate pipe arches shall be a multi-centered shape, made up of four circular arcs tangent to each other at their junctions and symmetrical about the vertical axis, and of the type, gage or thickness, and span specified.

Structural plate arches shall be a single-centered circular arc shape placed on a reinforced concrete foundation, and of the design, type, gage or thickness, and span as provided for in the Plans.

Structural plate underpasses shall be a multi-centered shape, made up of a variable number of circular arcs tangent to each other at their junctions and symmetrical about the vertical axis, and of the design, type, gage or thickness, and span specified.

9-05.6(2) Fabrication

The plates at longitudinal and circumferential seams shall be connected by bolts; the bolt holes shall be staggered in rows 2-inches apart, one hole being punched in the valley and one in the crest of each corrugation along both edges of each plate. Bolt holes on circumferential seams shall be spaced at approximate 12-inch intervals. No hole shall be closer to the edge of the plate than twice the diameter of the bolt.

The ends of structural plate pipes, pipe arches, arches, or underpasses shall not be mitered unless called for in the Plans, Special Provisions, or Standard Plan. If mitered ends are specified, the slope shall conform to the slope of the embankment in which the culvert is to be placed. The miter on pipe arches shall be limited to the top arc only.

9-05.6(3) Elliptical Fabrication

When elongated structural plate pipes are specified, they shall be fabricated 5 percent out of round to form an elliptical cross-section. The vertical axis (the longer axis of the elliptical section) shall be clearly marked on the plates before shipping.

9-05.6(4) Structural Plate Pipe Arch

Plates for structural plate pipe arches shall be formed so that the top shall be an arc of not more than 180 degrees nor less than 155 degrees; the bottom shall be an arc of not more than 50 degrees nor less than 10 degrees; and the top shall be joined at each end to the bottom by an arc having a radius between 18-inches and 31-inches and of not more than $87^{1}/_{2}$ degrees nor less than 75 degrees.

9-05.6(5) Structural Plate Arch

Structural plate arches and their foundations shall be as shown in the Plans.

9-05.6(6) Structural Plate Underpass

Structural plate underpasses shall be as provided for in the Standard Plans, or, in the case of a special design, as provided for in the Plans.

9-05.6(7) Concrete

Concrete required for constructing structural plate arch foundations shall be Class 3000 concrete in conformance with the requirements of Section 6-02.

Steel reinforcing bars shall conform to the requirements of Section 9-07.1.

9-05.6(8) Plates

9-05.6(8)A Corrugated Steel Plates

Galvanized corrugated steel plates for constructing structural plate pipe, pipe arches, arches, and underpasses, and nuts and bolts used in their assembly shall conform to the requirements of AASHTO M 167 except that the minimum mass of spelter coating on the plates shall be 3 ounces of zinc per square foot of double exposed surface. If the average spelter coating as determined from the required samples is less than 3 ounces, or if any one specimen shows less than 2.7 ounces, the lot samples shall be rejected. Nuts, bolts, and miscellaneous hardware shall be galvanized in accordance with AASHTO M 232.

9-05.6(8)B Corrugated Aluminum Plates

Aluminum alloy plates and fasteners intended for use in the construction of structural plate pipe, pipe arches, arches, and underpasses shall conform to the requirements of AASHTO M 219. Nuts, bolts, and miscellaneous hardware shall be galvanized in accordance with AASHTO M 232.

9-05.7 Concrete Storm Sewer Pipe

9-05.7(1) Plain Concrete Storm Sewer Pipe

Plain concrete storm sewer pipe shall conform to the requirements of AASHTO M 86, Class 2.

9-05.7(1)A Basis for Acceptance

The basis for acceptance of plain concrete storm sewer pipe shall be the same as specified in Section 9-05.3(1)B.

9-05.7(2) Reinforced Concrete Storm Sewer Pipe

Reinforced concrete storm sewer pipe shall conform to the requirements of AASHTO M 170 and shall be of the class noted in the Plans or in the Special Provisions. Section 7.3.1 of AASHTO M 170 shall be amended to require that both bells and spigots shall be reinforced in pipe 30-inches in diameter and greater.

The identification of the minor axis of elliptical reinforcement shall be in accordance with Section 9-05.3(2)D.

9-05.7(2)A Basis for Acceptance

The basis for acceptance of reinforced concrete storm sewer pipe shall be the same as specified in Section 9-05.3(2)B.

9-05.7(3) Concrete Storm Sewer Pipe Joints

All concrete storm sewer pipe shall be joined with rubber gaskets. The joints and gasket material shall meet the requirements of AASHTO M 198. Gasket material shall be handled and stored in accordance with Section 9-04.4(5).

9-05.7(4) Testing Concrete Storm Sewer Pipe Joints

When a particular type of pipe joint design, material or joining method has not previously been tested and approved, the following test shall be made on one test length of the assembled storm sewer pipe to qualify the design, material or method of joining the pipe. At the option of the Engineer, additional testing may be requested if subsequent field testing of installed pipe indicates difficulty in obtaining properly joined pipe. The tests will be conducted at the manufacturer's yard, and the manufacturer will be required to make such space and facilities available as required to conduct the tests in an efficient and workmanlike manner.

9-05.7(4)A Hydrostatic Pressure on Pipes in Straight Alignment

Hydrostatic pressure tests on pipes in straight alignment shall be made in accordance with the procedure outlined in paragraph 8(a) of AASHTO M 198, except that they shall be performed on an assembly consisting of not less than three nor more than five pipe sections selected from stock by the Engineer and assembled in accordance with standard installation instructions issued by the manufacturer. The end sections shall be bulkheaded and restrained against internal pressure.

9-05.7(4)B Hydrostatic Pressure Tests on Pipes in Maximum Deflected Position

Upon completion of the test for pipe in straight alignment, the test section shall be deflected until at least two of the joints have been deflected to the maximum amount shown in the manufacturer's standard installation instructions. When thus deflected, there shall be no leakage at the joints from an applied internal hydrostatic pressure of 5 psi.

9-05.7(4)C Hydrostatic Pressure Test on 15-inch Diameter and Larger Pipe Under Differential Load

The test sections shall be suitably supported so that one of the pipes of the test assembly is suspended freely between adjacent pipes, bearing only on the joints. The suspended pipe shall then be loaded, at its midpoint, in addition to the mass of the pipe, in accordance with the following schedule:

Diameter	Load
15-inches	7,400 lbs.
18-inches	8,800 lbs.
21-inches	10,000 lbs.
24-inches and over	11,000 lbs.

While under this load, the stressed joints shall show no leakage when subjected to an internal hydrostatic pressure of 5 psi. At the option of the manufacturer, $^1/_2$ of the load may be applied on the bell end of the suspended pipe in lieu of the full load on the center of the suspended pipe.

9-05.8 Vitrified Clay Sewer Pipe

This material shall not be used in Washington State Department of Transportation projects unless specified in the special provisions.

Vitrified clay sewer pipe shall conform to ASTM C 700, and all joints shall be factory manufactured in accordance with ASTM C 425.

9-05.9 Steel Spiral Rib Storm Sewer Pipe

Steel spiral rib storm sewer pipe shall meet the fabrication requirements of AASHTO M 36 and these Specifications. Zinc coated steel shall meet the material requirements of AASHTO M 218 (ASTM A929). Aluminum coated steel shall meet the material requirements of AASHTO M-274 (ASTM A929). The size, coating, metal, and protective treatment, if any, shall be as shown in the Plans or in the specifications.

The manufacturer of spiral rib storm sewer pipe shall furnish the Engineer a Manufacturer's Certificate of Compliance stating that the materials furnished comply in all respects with these Specifications. The Engineer may require additional information or tests to be performed by the Contractor at no expense to the Contracting Agency.

Unless otherwise specified, spiral rib storm sewer pipe shall be furnished with pipe ends cut perpendicular to the longitudinal axis of the pipe. Pipe ends shall be cut evenly. Spiral rib pipe shall be fabricated by using a continuous helical lock seam.

Spiral rib storm sewer pipe shall have helical ribs that project outwardly, be formed from a single thickness of material, and conform to one of the following configurations:

1. $^3/_4$-inch wide by $^3/_4$inch deep ribs at $7^1/_2$-inches on center.
2. $^3/_4$-inch wide by 1-inch deep ribs at $11^1/_2$-inches on center.
3. $^3/_4$-inch wide by $^5/_8$-inch deep ribs at 12-inches on center.

Pipe shall be fabricated with ends that can be effectively jointed with coupling bands.When it is required, spiral rib pipe shall be furnished with bituminous or polymer protective treatment 1 or 2 treated or paved. The bituminous treatment for spiral rib pipe shall conform to the requirements of Sections 9-05.4(3) and 9-05.4(4). Polymer coating shall conform to Section 9-05.4(5).

9-05.9(1) Continuous Lock Seam Pipe

Pipes fabricated with a continuous helical seam parallel to the rib may be used for full circle pipe. The seam shall be formed in the flat between ribs and shall conform to Sections 7.5.1 through 7.5.3 of AASHTO M 36.

9-05.9(1)A Basis for Acceptance

The basis for acceptance will be a qualification test, conducted by the State Materials Laboratory, for each manufacturer of spiral rib lock seam steel pipe. Only those specific pipe sizes and gasket materials, if any, approved under the qualification test will be accepted.

Continuous lock seam pipe shall be sampled and tested in accordance with AASHTO T 249.

9-05.9(2) Vacant

9-05.9(3) Coupling Bands

Coupling bands shall be of the same material as the pipe. Coupling bands and gaskets shall conform to Section 9-05.10(1).

9-05.10 Steel Storm Sewer Pipe

Steel storm sewer pipe shall conform to the requirements of Section 9-05.4 for steel culvert pipe, except that protective coating shall be Treatment 1 or 5, and be constructed of helically corrugated lock seam pipe. When gasketed helically corrugated lock seam steel pipe is called for, and the pipe is properly sized to meet hydraulic requirements, Treatment 5 is not required.

9-05.10(1) Coupling Bands

Coupling bands shall be as shown in the Standard Plans. Bands shall be fabricated of the same material as the pipe and shall meet all applicable requirements of AASHTO M 36. Bands may be up to three nominal thicknesses thinner than used for the pipe, but not thinner than 0.064-inches or thicker than 0.109-inches. Bands shall be coated with the same metallic protective treatment as the pipe but shall not be coated with any asphalt treatment. Bands shall be made by the same manufacturer as the steel pipe selected for installation.

Corrugations on the bands shall be the same size and shape as those on the pipe to be connected. Steel bolts and nuts for coupling bands shall meet the requirements of ASTM A 307 and shall be galvanized in accordance with AASHTO M 232. Steel angles, when required for coupling bands, shall meet the requirements of AASHTO M 36. When annular corrugated bands are used to connect helically corrugated lock-seam pipe, the seam shall be welded at the pipe ends prior to recorrugating to prevent unraveling of the seam. All welds shall develop the full strength of the parent metal.

Gaskets are required for all storm sewer installations. Gasket material for coupling bands shall meet the requirements of Section 9-04.4(3). Gaskets for Type D bands shall match the width of the band and have a minimum thickness of $^{3}/_{8}$-inch. O-ring gaskets for Type F bands shall have a cross-sectional diameter of $^{13}/_{16}$-inch for pipe diameters of 36-inches or smaller and $^{7}/_{8}$-inch for larger pipe diameters.

Type K coupling bands are not allowed for storm sewer applications.

9-05.10(2) Basis for Acceptance

The basis for acceptance of steel storm sewer pipe will be the same as specified in Section 9-05.4, except when gasketed helically corrugated lock seam steel pipe is called for. A qualification test conducted by the State Materials Laboratory will be required for each manufacturer of gasketed helically corrugated lock seam steel pipe. Only those specific pipe sizes and gasket materials approved under the qualification test will be accepted.

9-05.11 Aluminum Storm Sewer Pipe

Aluminum storm sewer pipe shall conform to the requirements of Section 9-05.5 for aluminum culvert pipe, and the pipe shall be constructed of helically corrugated lock seam aluminum pipe.

9-05.11(1) Coupling Bands

Coupling bands for aluminum pipe shall be as shown in the Standard Plans. Bands shall be fabricated of the same material as the pipe and shall meet all applicable requirements of AASHTO M 196, except the band thickness shall not be more than 0.105-inches or less than 0.060-inches. All other requirements of Section 9-05.10(1) shall apply.

9-05.11(2) Basis for Acceptance

The basis for acceptance of aluminum storm sewer pipe will be the same as specified in Section 9-05.0, except when gasketed helically corrugated lock seam aluminum pipe is called for. A qualification test, conducted by the State Materials Laboratory, will be required for each manufacturer of gasketed helically corrugated lock seam aluminum pipe. Only those specific pipe sizes and gasket materials approved under the qualification test will be accepted.

9-05.12 Polyvinyl Chloride (PVC) Pipe

9-05.12(1) Solid Wall PVC Culvert Pipe, Solid Wall PVC Storm Sewer Pipe, and Solid Wall PVC Sanitary Sewer Pipe

Solid wall PVC culvert pipe, solid wall PVC storm sewer pipe, and solid wall PVC sanitary sewer pipe and fittings shall be solid wall construction and shall conform to the requirements of ASTM D 3034 SDR 35 for pipe up to 15-inch diameter and ASTM F 679, Type 1 only, for pipe sizes 18- to 27-inch diameter.

Joints for solid wall PVC pipe shall conform to ASTM D 3212 using elastomeric gaskets conforming to ASTM F 477.

Fittings for solid wall PVC pipe shall be injection molded, factory welded, or factory solvent cemented.

9-05.12(2) Profile Wall PVC Culvert Pipe, Profile Wall PVC Storm Sewer Pipe, and Profile Wall PVC Sanitary Sewer Pipe

Profile wall PVC culvert pipe and profile wall PVC storm sewer pipe shall meet the requirements of AASHTO M 304 or ASTM F 794 Series 46. Profile wall PVC sanitary sewer pipe shall meet the requirements of ASTM F 794 Series 46. The maximum pipe diameter shall be as specified in the Qualified Products List.

Joints for profile wall PVC culvert pipe shall conform to ASTM D 3212 using elastomeric gaskets conforming to ASTM F 477, or as approved through the State Materials Laboratory.

Qualified producers are identified in the Qualified Products List. Qualification for each producer requires joint system conformation to ASTM D 3212 using elastomeric gaskets conforming to ASTM F 477 and a formal quality control plan for each plant proposed for consideration.

A producer's Certificate of Compliance shall be required and shall accompany the materials delivered to the project. The certificate shall clearly identify production lots for all materials represented. The Contracting Agency may conduct verification tests of pipe stiffness or other properties as it deems appropriate.

Fittings for profile wall PVC pipe shall meet the requirements of AASHTO M 304 or ASTM F 794 Series 46.

9-05.13 Ductile Iron Sewer Pipe

This material shall not be used in Washington Department of Transportation projects unless specified in the special provisions.

Ductile iron pipe shall conform to ANSI A 21.51 or AWWA C 151 and shall be cement mortar lined, push-on joint, or mechanical joint. The ductile iron pipe shall be Class 50 or the class indicated on the Plans or in the Special Provisions.

Joints for ductile iron pipe shall be rubber gasketed conforming to the requirements of ANSI A 21.11 or AWWA C-111.

Cast iron fittings may be used with ductile iron pipe. Saddles fastened to pipe with external bands shall not be acceptable on any new system. Normally, all fittings shall be the same material as the pipe being connected, except that fittings using other materials or constructed with more than one material may be used subject to the approval of the Engineer. Fittings shall have sufficient strength to withstand handling and load stresses normally encountered.

9-05.14 ABS Composite Sewer Pipe

This material shall not be used in Washington Department of Transportation projects unless specified in the special provisions.

ABS composite pipe shall meet the requirements of AASHTO M 264.

ABS composite pipe shall be provided with Type OR (flexible gasketed) joints. Rubber gasketed joints shall conform to applicable provisions of ASTM C 443.

Fittings for ABS composite pipe shall be specifically designed for connection to ABS composite pipe with solvent cement. Normally, all fittings shall be the same material as the pipe being connected, except that fittings using other materials or constructed with more than one material may be used subject to the approval of the Engineer. Fittings shall have sufficient strength to withstand handling and load stresses normally encountered.

9-05.15 Metal Castings

Metal castings for drainage structures shall not be dipped, painted, welded, plugged, or repaired.

Porosity in metal castings for drainage structures shall be considered a workmanship defect subject to rejection by the Engineer.

9-05.15(1) Manhole Ring and Cover

Castings for manhole rings shall be gray-iron conforming to the requirements of AASHTO M 105, Grade 30B. Covers shall be ductile iron conforming to ASTM A 536, Grade 80-55-06.

All covers shall be interchangeable within the dimensions shown in the Standard Plans. Manhole rings and covers shall meet the strength requirements of Federal Specification RR-F-621E. All mating surfaces shall be machine finished to ensure a nonrocking fit.

The horizontal surface and inside vertical recessed face of the ring, and the horizontal seating surface and vertical outside edge of the cover, shall be machine finished to the following tolerances:

Ring	+3/32-inch to -3/32-inch
Cover	+3/32-inch to -3/32-inch

All manhole rings and covers shall be identified by the name or symbol of the manufacturer and country of casting origin. This identification shall be in a plainly visible location when the ring and cover are installed. Ductile iron shall be identified by the following, "DUC" or "DI." The manufacturer's identification and material identification shall be adjacent to each other and shall be minimum ½-inch to maximum 1-inch high letters, recessed to be flush with the adjacent surfaces.

9-05.15(2) Metal Frame, Grate and Solid Metal Cover for Catch Basins or Inlets

Castings for metal frames for catch basins and inlets shall be cast steel, gray iron, or ductile iron as specified in Sections 9-06.8, 9-06.9, or 9-06.14, and as shown in the Standard Plans. Castings shall meet the strength requirements of Federal Specification RR-F-621E.

Castings for grates and solid metal covers for catch basins and inlets shall be cast steel or ductile iron as specified in Sections 9-06.8 or 9-06.14, and as shown in the Standard Plans. Castings shall meet the strength requirements of Federal Specifications RR-F-621E. The foundry name and material designation shall be embossed on the top of the grate. The material shall be identified by the following: "CS" for cast steel or "DUC" or "DI" for ductile iron and shall be located near the manufacturer's name.

Grates and covers shall be seated properly to prevent rocking, including the replacement of existing covers with solid metal covers. After seating, the frame and grate or frame and cover shall be maintained as a unit. Alternate designs are acceptable provided they conform to the manufacturer's shop drawings approved prior to award of the contract.

9-05.15(3) Cast Metal Inlets

The castings for cast metal inlets shall be cast steel or ductile iron as specified in Section 9-06.8 or Section 9-06.14 and as shown in the Standard Plans. Alternate plans are acceptable provided they conform to the fabricator's shop drawings approved prior to award of contract.

9-05.16 Grate Inlets and Drop Inlets

Steel in grates, angles, and anchors for grate inlets shall conform to ASTM A 36, except structural tube shall conform to ASTM A 500, Grade B, and structural shapes may conform to ASTM A 992. After fabrication, the steel shall be galvanized in accordance with AASHTO M 111, or galvanized with a hot-sprayed (plasma flame applied) 6 mil minimum thickness plasma coating.

Steel grating shall be fabricated by weld connections. Welds, welding procedures, and welding materials shall conform with the AWS D1.1/D1.1M, latest edition, Structural Welding Code.

Alternate grate designs will be permitted, with the approval of the Engineer, providing the hydraulic capacity is not decreased, the overall dimensions are the same allowing the grate to be interchangeable, and the strength is essentially equal to the grate shown in the Standard Plan or the Plans.

The Contractor has the option of furnishing either cast-in-place or precast inlets unless otherwise shown in the Plans. Alternate designs are acceptable provided they conform to the fabricator's shop drawings approved prior to award of the contract.

9-05.17 Aluminum Spiral Rib Storm Sewer Pipe

Aluminum spiral storm sewer pipe shall meet the fabrication requirements of AASHTO M 196 and these Specifications. Aluminum alloy shall meet the material requirements of AASHTO M 97 (ASTM B744). The size and corrugation shall be as shown in the Plans or in the Specifications. The size, metal, and protective treatment shall be as shown in the Plans or in the Specifications.

The manufacturer of spiral rib storm sewer pipe shall furnish to the Engineer a Manufacturer's Certificate of Compliance stating that the materials furnished comply in all respects with these Specifications. The Engineer may require additional information or tests to be performed by the Contractor at no expense to the Contracting Agency.

Unless otherwise specified, spiral rib storm sewer pipe shall be furnished with pipe ends cut perpendicular to the longitudinal axis of the pipe. Pipe ends shall be cut evenly. Spiral rib pipe shall be fabricated by using a continuous helical lock seam.

Spiral rib storm sewer pipe shall have helical ribs that project outwardly, be formed from a single thickness of material, and conform to one of the following configurations:

1. $^{3}/_{4}$-inch wide by $^{3}/_{4}$-inch deep ribs at $7^{1}/_{2}$-inches on center.
2. $^{3}/_{4}$-inch wide by 1-inch deep ribs at $11^{1}/_{2}$-inches on center.
3. $^{3}/_{4}$-inch wide by $^{5}/_{8}$-inch deep ribs at 12-inches on center.

9-05.17(1) Continuous Lock Seam Pipe

Pipes fabricated with a continuous helical lock seam parallel to the rib may be used for full circle pipe. The lock seam shall be formed in the flat between ribs and shall conform to Sections 13.2.1 through 13.2.5 of AASHTO M 196.

9-05.17(1)A Basis for Acceptance

The basis for acceptance will be a qualification test, conducted by the State Materials Laboratory, for each manufacturer of spiral rib lock seam pipe. Only those specific pipe sizes and gasket materials, if any, approved under the qualification test, will be accepted.

Continuous lock seam pipe shall be sampled and tested in accordance with AASHTO T 249.

9-05.17(2) Coupling Bands

Coupling bands shall be of the same material as the pipe. Coupling bands and gaskets shall conform to Section 9-05.10(1).

9-05.18 Safety Bars for Culvert Pipe

Steel pipe used as safety bars and steel pipe used as sockets shall conform to ASTM A 53, Grade B. Steel tubing used as safety bars shall conform to ASTM A 500, Grade B. Steel plate shall conform to ASTM A 36. All parts shall be galvanized after fabrication in accordance with AASHTO M 111.

9-05.19 Corrugated Polyethylene Culvert Pipe

Corrugated polyethylene culvert pipe shall meet the requirements of AASHTO M 294 Type S or D for pipe 12-inch to 60-inch diameter.

Joints for corrugated polyethylene culvert pipe shall be made with either a bell/bell or bell and spigot coupling and shall incorporate the use of a gasket conforming to the requirements of ASTM D 1056, ASTM F 477, or ASTM D 5249. All gaskets shall be factory installed on the coupling or on the pipe by the producer. Qualified producers and approved joints are listed in the Qualified Products Lists.

Qualification for each producer of corrugated polyethylene culvert pipe requires an approved joint system and a formal quality control plan for each plant proposed for consideration.

A producer's Certificate of Compliance shall be required and shall accompany the materials delivered to the project. The certificate shall clearly identify production lots for all materials represented. The Contracting Agency may conduct verification tests of pipe stiffness or other properties as it deems appropriate.

9-05.20 Corrugated Polyethylene Storm Sewer Pipe

Corrugated polyethylene storm sewer pipe and fittings shall meet the requirements of AASHTO M 294 Type S or D. The maximum pipe diameter for corrugated polyethylene storm sewer pipe shall be the diameter for which a producer has submitted a qualified joint. Qualified producers are listed in the Qualified Products List. Fittings shall be blow molded, rotational molded, or factory welded.

All joints for corrugated polyethylene storm sewer pipe shall be made with a bell/bell or bell and spigot coupling and shall conform to ASTM D 3212 using elastomeric gaskets conforming to ASTM F 477. All gaskets shall be factory installed on the pipe in accordance with the producer's recommendations.

Qualification for each producer or corrugated polyethylene storm sewer pipe requires joint system conformance to ASTM D 3212 using elastomeric gaskets conforming to ASTM F 477 and a formal quality control plan for each plant proposed for consideration.

A producer's Certificate of Compliance shall be required and shall accompany the materials delivered to the project. The certificate shall clearly identify production lots for all materials represented. The Contracting Agency may conduct verification tests of pipe stiffness or other properties as it deems appropriate.

9-06 STRUCTURAL STEEL AND RELATED MATERIALS

9-06.1 Structural Carbon Steel

Structural carbon steel shall conform to AASHTO M 270, Grade 36, except as otherwise noted.

9-06.2 Structural Low Alloy Steel

Structural low alloy steel shall conform to AASHTO M 270, Grade 50 or 50W as specified in the Plans or Special Provisions, except as otherwise noted.

9-06.3 Structural High Strength Steel

Structural high strength steel shall be high yield strength, quenched and tempered structural steel conforming to AASHTO M 270, Grades 70W, 100, or 100W as specified in the Plans or Special Provisions, except as otherwise noted.

9-06.4 Vacant

9-06.5 Bolts

9-06.5(1) Unfinished Bolts

Unfinished bolts (ordinary machine bolts) shall conform to the specification requirements of ASTM A 307 Grade A or B. Nuts shall comply with ASTM A 563 Grade A requirements. Washers, unless otherwise specified, shall meet ASTM F 844 specifications.

The Contractor shall submit a Manufacturer's Certificate of Compliance for the bolts, nuts, and washers prior to installing any of them.

9-06.5(2) Vacant

9-06.5(3) High Strength Bolts

High strength bolts for structural steel joints shall conform to the requirements of AASHTO M 164 or M 253 Type 1, 2, or 3.

Bolts conforming to AASHTO M 164, having an ultimate tensile strength above 145 ksi and are galvanized in accordance with AASHTO M 232, shall be tested for embrittlement. Embrittlement testing shall be conducted after galvanization in accordance with ASTM F 606, Section 7. The Manufacturer's Certificate of Compliance for the lot provided shall show the ultimate tensile strength test results. Bolts conforming to AASHTO M 253 shall not be galvanized. AASHTO M 253 Type 1 and 2 bolts shall be painted with two coats of zinc rich paint, formula A-9-73, consisting of a minimum dry film thickness of 2 mils per coat.

Unpainted and nongalvanized bolts shall conform to AASHTO M 164 and M 253 Type 3.

Nuts for high strength bolts shall meet the following requirements:

AASHTO M 164 Bolts	
Black or galvanized Type 1	AASHTO M 291 Grade C, C3, DH, and DH3
AASHTO M 292 Grade 2H	
Black weathering Type 3	AASHTO M 291 Grade C3 and DH3
Galvanized Type 1	AASHTO M291 Grade DH AASHTO M 292 Grade 2H
AASHTO M 253 Bolts	
Black Type 1 and 2	AASHTO M 291 Grade DH, DH3 AASHTO M 292 Grade 2H
Black weathering Type 3	AASHTO M 291 Grade DH3

Nuts that are to be galvanized shall be tapped oversized the minimum required for proper assembly. The amount of overtap shall be such that the nut will assemble freely on the bolt in the coated condition and shall meet the mechanical requirements of AASHTO M 291 and the rotational capacity test specified in AASHTO M 164.

Galvanized nuts shall be lubricated in accordance with AASHTO M 291 including supplementary requirement S2. Documentation shall include the name, method of application, and dilution of the lubricant applied to the nuts.

Washers for AASHTO M 164 Type 1 and 3 bolts; and AASHTO M 253 Type 1, 2, and 3 bolts shall meet the requirements of AASHTO M 293. The surface condition and weathering characteristics of the washers shall be the same as for the bolts being specified.

Direct Tension Indicators shall conform to the requirements of ASTM F 959 and may be used with either AASHTO M 164 or M 253 bolts. Direct tension indicators shall be galvanized by mechanical deposition in accordance with AASHTO M 298 class 55. Hot dip galvanizing will not be allowed.

All bolts, nuts, and direct tension indicators shall be marked and identified as required in the pertinent specifications.

Lock-pin and collar fasteners which meet the materials, manufacturing, and chemical composition requirements of AASHTO M 164 or AASHTO M 253, and which meet the mechanical property requirements of the same specification in full size tests, and which have a body diameter and bearing areas under lock-pin head and collar not less than those provided by a bolt and nut of the same nominal size may be used. The Contractor shall submit a detailed installation procedure to the Engineer for approval. Approval to use a lock-pin and collar fasteners will be given by the Engineer prior to use on these types of fasteners.

The Contractor shall provide Manufacturer's Certificate of Compliance for all bolts, nuts, washers, and load indicators. The Manufacturer's Certificate of Compliance shall include certified mill test reports and test reports performed on the finished bolt confirming that all of the materials provided meet the requirements of the applicable AASHTO or ASTM specification. The documentation shall also include the name and address of the test laboratory, the date of testing, the lot identification of the bolts and nuts, and coating thickness for galvanized bolts and nuts. Shipping containers (not lids) shall be marked with the lot identification of the item contained therein.

Bolts shall be sampled prior to incorporating into a structure. For the purposes of selecting samples, a lot of bolts shall be the quantity of bolts of the same nominal diameter and same nominal length in a consignment shipped to the project site. The minimum number of samples from each lot shall be as follows:

Lot Size	Sample Size[1,2]
0 to 50	*
51 to 150	4
151 to 1,200	6
1,201 to 10,000	10
10,001 to 35,000	16
35,001 and over	24

*Manufacturer's Certificate of Compliance — samples not required.

[1]If bolts are galvanized, increase the sample size by 1.5 times the table value for the number of bolts being sampled.

[2]Nuts, washers, and load indicator devices shall be sampled at the same frequency as the bolts.

All testing of bolts, nuts, washers, and load indicating devices shall be performed on specimens as they are to be installed.

All samples shall include a Manufacturer's Certificate of Compliance for each lot of bolts provided as defined in Section 1-06.3.

9-06.5(4) Anchor Bolts

Anchor bolts shall meet the requirements of ASTM A 449 or AASHTO M 164. Galvanized anchor bolts having an ultimate tensile strength above 145 ksi shall be tested for embrittlement in accordance with ASTM A 143 unless the length is less than five times the nominal bolt diameter, then they shall be tested in accordance with ASTM F 606, Section 7. The Manufacturer's Certificate of Compliance for the lot provided shall show the ultimate tensile strength test results.

Nuts for ASTM A 449 black anchor bolts shall conform to AASHTO M 291, Grade C. Nuts for ASTM A 449 galvanized bolts shall conform to AASHTO M 291, Grade DH and shall conform to the lubrication requirements in Section 9-06.5(3). Nuts for AASHTO M 164 black anchor bolts shall conform to AASHTO M 291, Grade C, C3, DH, and DH3 or AASHTO M 292, Grade 2H. Nuts for AASHTO M 164 galvanized anchor bolts shall conform to AASHTO M 291, Grade DH or AASHTO M 292, Grade 2H. Washers for ASTM A 449 anchor bolts shall conform to AASHTO M 293. Washers for AASHTO M 164 anchor bolts shall conform to ASTM F 436.

The bolts shall be tested by the manufacturer in accordance with the requirements of the pertinent specification and as specified in these Specifications. Anchor bolts, nuts, and washers shall be inspected prior to shipping to the project site. The Contractor shall submit to the Engineer for approval a Manufacturer's Certificate of Compliance for the anchor bolts, nuts, and washers, as defined in Section 1-06.3. If the Engineer deems it appropriate, the Contractor shall provide a sample of the anchor bolt, nut, and washer for testing.

All bolts, nuts, and washers shall be marked and identified as required in the pertinent specification.

9-06.6 Vacant

9-06.7 Vacant

9-06.8 Steel Castings

Steel castings shall conform to the requirements of AASHTO M 103, Mild to Medium Strength Carbon Steel Castings for General Application, grade 70-36, unless otherwise designated in the Plans or in the Special Provisions.

9-06.9 Gray Iron Castings

Gray iron castings shall conform to the requirements of AASHTO M 105. The class of castings to be furnished shall be that designated in the Plans or in the Special Provisions.

9-06.10 Malleable Iron Castings

Malleable iron castings shall conform to the requirements of ASTM A 47.

9-06.11 Steel Forgings and Steel Shafting

Steel forgings shall conform to the requirements of AASHTO M 102. The classes of forgings to be furnished shall be those specified in the Plans or in the Special Provisions.

Steel shafting shall conform to the requirements of AASHTO M 169, Grade Designation 1016 to 1030 inclusive, unless otherwise specified.

9-06.12 Bronze Castings

Bronze castings shall conform to the requirements of AASHTO M 107, Bronze Castings for Bridges and Turntables.

9-06.13 Copper Seals

Copper sheets for seals shall conform to the requirements of AASHTO M 138. They shall be UNS C12500, light cold rolled, and furnished in flat sheets each not less than 0.018-inch in thickness.

All splices or joints shall be carefully brazed or soldered to produce a continuous watertight seal for the full length of each unit.

9-06.14 Ductile Iron Castings

Ductile iron castings shall conform to the requirements of ASTM A 536, Grade 80-55-06, unless otherwise specified in the Plans or in the Special Provisions.

9-06.15 Welded Shear Connectors

Welded shear studs shall be made from cold drawn bar stock conforming to the requirements of AASHTO M 169. Grades 1010 through 1020, inclusive, either semi-killed or killed deoxidation.

The material shall conform to the following mechanical properties:

Tensile Strength	60,000 psi min.
Yield Strength	50,000 psi min.
Elongation	20% min.
Reduction of Area	50% min.

Mechanical properties shall be determined in accordance with AASHTO Methods and Definitions T 244.

At the manufacturer's option, mechanical properties of the studs shall be determined by testing either the steel after cold finishing, or the full diameter finished studs.

9-06.16 Roadside Sign Structures

All bolts, nuts, washers, cap screws, and coupling bolts shall conform to AASHTO M 164 and Section 9-06.5(3). All connecting hardware shall be galvanized after fabrication in accordance with AASHTO M 232.

Posts for single post sign structures shall meet the requirements of ASTM A 500 Grade B or ASTM A 53 Grade B, Type E or S.

Posts for multiple post sign structures shall conform to either ASTM A 36 or ASTM A 992. Posts conforming to either ASTM A 588 or ASTM A 572 Grade 50 may be used as an acceptable alternate to the ASTM A 36 and ASTM A 992 posts. All steel not otherwise specified shall conform to either ASTM A 36 or ASTM A 992.

Triangular base stiffeners for one-directional multi-post sign posts shall conform to either ASTM A 588 or ASTM A 572, Grade 50.

All steel, including posts, base plates, and base stiffeners, shall be galvanized after fabrication in accordance with AASHTO M111.

Base connectors for multiple directional steel breakaway posts shall conform to the following:

Brackets	Aluminum Alloy 6061 T-6
Bosses for Type 2B Brackets	ASTM A 582
Anchor Ferrules	Type 304 stainless steel for threaded portion. AISI 1038 steel rod and AISI 1008 coil for cage portion.

Anchor couplings for multiple directional steel breakaway posts shall conform to AMS 6378D with a tensile breaking strength range as follows:

Type 2A	17,000 to 21,000 lb.
Type 2B	47,000 to 57,000 lb.

For multi-directional breakaway base connectors, shims shall conform to ASTM A 653, SS Grade 33, Coating Designation G 165. For one-directional breakaway base connectors, single post or multi-post, shims shall be fabricated conforming to ASTM B 36.

9-06.17 Vacant

9-06.18 Metal Bridge Railing

Metal bridge railing shall conform to the type and material specifications set forth in the Plans and Special Provisions. Steel used for metal railings, when galvanized after fabrication in accordance with AASHTO M 111, shall have a controlled silicon content of either 0.00 to 0.04 percent or 0.15 to 0.25 percent. Mill test certificates verifying the silicon content of the steel shall be submitted to both the galvanizer and the Engineer prior to beginning galvanizing operations.

Section 8, part (b) of the Aluminum Association Standard Specifications for Aluminum Railing Posts Alloy A 344-T4 is hereby revised to provide that no X-ray inspection will be required after a foundry technique has been established for each mold which will ensure production of castings which are free from harmful defects. Inspection for approval of castings will be made by the Engineer after the finished castings have been anodized as noted in the Plans.

Welding of aluminum shall be in accordance with Section 9-28.14(3).

9-06.19 Vacant

9-06.20 Vacant

9-06.21 Vacant

9-06.22 Bolts, Washers, and Other Hardware

Ordinary machine bolts and flat head bolts shall be made from commercial bolt stock meeting the specifications of ASTM A 307, and shall be grade A. Drift bolts and dowels may be either wrought iron or medium steel. Washers may be cast iron or malleable iron or may be cut from medium steel or wrought iron plate.

All bolts and other hardware which are to be galvanized and which require bending or shaping shall be hot forged to the required shape before galvanizing. Cold bending of such material will not be permitted because of the tendency toward embrittlement during the galvanizing process. Galvanizing shall be in accordance with AASHTO M 232.

Split rings for log cribbing of 4-inches inside diameter shall be manufactured from hot rolled, low carbon steel conforming to ASTM A 711 AISI, Grade 1015. Each ring shall form a true circle with the principle axis of the cross section of the ring metal parallel to the geometric axis of the ring. The thickness of the metal section shall be 0.195-inch plus or minus 0.010-inch and the section shall be beveled from the central portion toward the edges to a thickness of 0.145-inch plus or minus 0.010-inch. It shall be cut through in one place in its circumference to form a tongue and slot. Split ring connectors shall be galvanized in accordance with AASHTO M 232.

Spike-grid timber connectors shall be manufactured according to ASTM A 47 for malleable iron castings. They shall consist of 4 rows of opposing spikes forming a 4⅛-inch square grid with 16 teeth which are held in place by fillets which are diamond shaped in cross section.

Nails shall be round wire of standard form. Spikes shall be wire spikes or boat spikes, as specified in the Plans. Bolts, dowels, washers, and other hardware, including nails, shall be black or galvanized as specified in the Plans, but if not so specified shall be galvanized when used in treated timber structures.

9-07 REINFORCING STEEL

9-07.1 General

9-07.1(1) Acceptance by Manufacturer's Certification

Reinforcing steel may be accepted by the Engineer based on the Manufacturer's Certificate of Compliance.

9-07.1(1)A Acceptance of Materials

Steel reinforcing bar manufacturers use either an English or a Metric size designation while stamping rebar. The actual size of the bar, whether stamped with an English or a Metric size designation is acceptable. The contract plans and the standard plans will continue to use an English size designation. The table below shows the comparable reinforcing steel bar size designations in the both units of measure:

English Designation	Bar Diameter	Metric Designation
#3	(0.375-inches)	#10
#4	(0.500-inches)	#13
#5	(0.625-inches)	#16
#6	(0.750-inches)	#19
#7	(0.875-inches)	#22
#8	(1.000-inches)	#25
#9	(1.128-inches)	#29
#10	(1.270-inches)	#32
#11	(1.410-inches)	#36
#14	(1.690-inches)	#43
#18	(2.260-inches)	#57

9-07.1(2) Bending

Steel reinforcing bars shall be cut and bent by careful and competent workmen. They shall be bent cold to templates, which shall not vary appreciably from the shape and dimension shown in the Plans.

Hooks and bends of steel reinforcing bars shall be bent to the following inside diameters unless shown otherwise in the Plans:

Bar Size	Stirrups and Ties	All Other Bars
No. 3	1½″	6 bar diameters
No. 4	2″	6 bar diameters
No. 5	2½″	6 bar diameters
No. 6	4½″	6 bar diameters
No. 7	5¼″	6 bar diameters
No. 8	6″	6 bar diameters
No. 9 through No. 11		8 bar diameters
No. 14 through No. 18		10 bar diameters

The supplementary requirements of AASHTO M 31 for bend tests shall apply to size No. 14 and No. 18 steel reinforcing bars which have hooks or bends.

9-07.1(3) Lengths

Net lengths of bent bars shown in the "LENGTH" column of the bar list in the plans are rounded to the nearest inch. Net length is the length of bar after all bend deductions are subtracted from the gross length.

The following bend deductions per 90 degrees bend have been subtracted from the gross length:

Bar Size	Stirrups and Ties	All Other Bars
No. 3	¾″	1″
No. 4	1″	1¼″
No. 5	1¼″	1½″
No. 6	1⅞″	1⅞
No. 7	2¼″	2¼″
No. 8	2½″	2½″
No. 9		3⅜″
No. 10		3¾″
No. 11		4⅛″
No. 14		5¾″
No. 18		7⅝″

For bends other than 90 degrees, a direct proportion of these deductions will be used. The bend deductions listed will apply, except where bending radii are shown in the Plans.

For standard hooks on the ends of bars, the following hook lengths, in addition to the out to out detailed dimension, have been provided:

	Length Added for One Hook				
	180° Hook	135° Hook		90° Hook	
Bar Size	All Bars	Seismic Ties	All Other Bars	Stirrup and Ties	All Other Bars
No. 3	5⅛″	4⅞″	3⅝″	2⅞″	5⅛″
No. 4	6″	6½″	4½″	3½″	6¾″
No. 5	6⅞″	8″	5⅜″	4⅜″	8½″
No. 6	8¼″	10¾″	7¾″	10⅛″	10⅛″
No. 7	9⅝″	1′-0½″	9″	11⅞″	11⅞″
No. 8	11″	1′-2¼″	10¼″	1′-1½″	1′-1½″
No. 9	1′-2⅞″				1′-3⅞″
No. 10	1′-4⅝″				1′-5⅞″
No. 11	1′-6½″				1′-7⅞″
No. 14	2′-1⅞″				2′-0¾″
No. 18	2′-10½″				2′-9⅛″

9-07.1(4) Vacant

9-07.2 Deformed Steel Bars

Deformed steel bars for concrete reinforcement shall conform to the requirements of AASHTO M 31, Deformed and Plain Billet Steel Bars for Concrete Reinforcement, Grade 60, or ASTM A 706, Low Alloy Steel, Deformed Bars for Concrete Reinforcement. However, in computing the ultimate unit tensile stress from test data, the area may be corrected for mass per linear foot of the bar within the weight tolerances listed. No such correction for mass shall be used in calculating the yield stress; the nominal area of the bar, as given in Table 1 of AASHTO M 31 or ASTM A 706, shall be used in this computation.

Deformed steel bars are referred to in the Plans and specifications by number: for example, No. 3, No. 4, No. 5, etc.

9-07.3 Epoxy Coated Steel Reinforcing Bars

Epoxy coated rebar shall be coated according to AASHTO M 284 with the additional following modifications:

1. The list of steel reinforcing bars acceptable for coating shall include ASTM A 706.
2. The Contractor shall furnish a written certification that properly identifies the material, the number of each batch of coating material used, quantity represented, date of manufacture, name and address of manufacturer, and a statement that the supplied coating material meets the requirements of AASHTO M 284.
3. Prior to coating the bars, the Contractor shall submit to the Engineer for review, the coating material manufacturer's recommendation on the proper use and application requirements of the coating material. For Pre Approved Epoxy Coating Facilities this information will be available to the Fabrication Inspector upon request.
4. A certification stating that all bars have been coated in accordance with the coating material manufacturer's recommendations and these Specifications shall be furnished with each shipment. This certification shall include for each bar size the preheat temperatures, cure times, thickness checks, holidays detected, and test results. Two copies of these certifications shall be furnished to the Engineer.
5. The Contractor shall give advance notice to the Engineer of the coating schedule in the coating plant so that Contracting Agency inspection may be provided. The Engineer may inspect the coated bars at the coating plant for approval.
6. The patching material, compatible with the coating material and inert in concrete, shall be supplied with each shipment.
7. For projects where epoxy coated steel reinforcing bars are used in the top mat of bridge decks only, the maximum amount of damage to the coating shall not exceed 0.25 percent of the surface area of each bar.
8. The thickness of epoxy coating shall be 10 mils plus or minus 2 mils.
9. Samples, when required, shall be shipped to the Washington State Department of Transportation, Materials Laboratory, 1655 South 2nd Ave, Tumwater, Washington 98504.

9-07.4 Plain Steel Bars

Where plain steel bars are specified, they shall conform to the chemical and physical properties of AASHTO M 31, Grade 60, unless specifically noted otherwise. Plain steel bars are indicated in the Plans and specifications by fractions of an inch; for example, ⅜-inch Ø, ½-inch Ø, ⅝-inch Ø, etc.

9-07.5 Dowel Bars (For Cement Concrete Pavement)

Dowel bars shall be plain steel bars of the dimensions shown in the Standard Plans. They shall conform to AASHTO M 31, Grade 60 or AASHTO M 255, Grade 60, and shall be coated in accordance with AASHTO M 284. The ends of the bars shall be coated to a minimum of 4 mils. In addition, the requirements of Section 9-07.3, Items 2, 3, 4, 5, 6, 8, and 9 shall apply.

9-07.6 Tie Bars (For Cement Concrete Pavement)

Tie bars shall conform to the requirements of the Standard Specifications for Deformed Billet Steel Bars for Concrete Reinforcement, AASHTO M 31, Grade 60 and shall be coated in accordance with AASHTO M 284.

The form of the deformed bar shall be subject to approval by the Engineer.

Tie bars shall be free from dirt, grease, or other defects affecting the strength or bond with the concrete.

9-07.7 Wire Mesh

Wire mesh for concrete reinforcement shall conform to the requirements of AASHTO M 55, Welded Steel Wire Fabric for Concrete Reinforcement or AASHTO M 221, Welded Deformed Steel Wire Fabric for Concrete Reinforcement. All wire mesh shall be of an approved kind and quality of manufacture.

9-07.8 Deformed Wire

Deformed wire shall conform to the requirements of AASHTO M 225, Deformed Steel Wire for Concrete Reinforcement.

Deformed wire is noted in the Plans and specifications by the letter D, followed by a number indicating the cross sectional area of the wire; for example, D2, D5, D20, etc.

9-07.9 Cold Drawn Wire

Cold drawn wire shall conform to the requirements of AASHTO M 32, Cold Drawn Steel Wire for Concrete Reinforcement.

Cold drawn wire is noted in the Plans and specifications by the letter W followed by a number indicating the cross sectional area of the wire; for example, W2, W5, W20, etc.

9-07.10 Prestressing Reinforcement Strand

Prestressing reinforcement shall be ½-inch diameter for precast-prestressed concrete piles and ½-inch or 0.6-inch diameter for pretensioned concrete girders, post-tensioned segmental precast concrete girders, or cast-in-place prestressed concrete.

Prestressing reinforcement shall be mill bright high tensile strength seven wire low relaxation strand conforming to the requirements of AASHTO M 203, Grade 270.

All prestressing reinforcement furnished for a given structural member shall have a maximum elongation differential of 3 percent at stress of 0.8 of the ultimate strength of the prestressing steel. Each reel of prestressing reinforcement shall be accompanied by a Manufacturer's Certificate of Compliance, a mill certificate, and a test report. The mill

certificate and test report shall include the chemical composition, the yield and ultimate strengths, elongation at rupture, modulus of elasticity, and the stress strain curve for the actual prestress reinforcing intended for use. All values certified shall be based on test values and actual sectional areas of the material being certified.

For every 5 reels furnished, one sample, not less than 5-feet long, shall be sent to the Engineer for testing. Samples of the furnished reels with Manufacturer's Certificate of Compliance, a mill certificate, and test report may be shipped directly by the manufacturer to the Engineer. An independent inspector, approved by the Contracting Agency, shall be present during sampling and shall provide a written certification to the Engineer.

9-07.11 Prestressing Reinforcement Bar

High-strength steel bars shall conform to AASHTO M 275, Type II.

Nuts shall conform to either ASTM A 29 Grade C1045, or ASTM A 536 Grade 100-70-03, and shall be capable of developing the larger of either 100 percent of the minimum ultimate tensile strength (MUTS), or 95 percent of the actual ultimate tensile strength (AUTS), of the bar. The anchor nuts shall conform to the specified strength requirement while permitting a maximum 5 degree misalignment between the nut and the bearing plate. A minimum of three tests, each from a different heat, are required.

Couplers, if required, shall be AASHTO M 169 Grade 1144, or equivalent steel, developing the larger of either 100 percent of the MUTS, or 95 percent of the AUTS, of the bar. The test shall be performed with the coupler having a one inch unengaged segment between the two coupled bars. A minimum of three tests, each from a different heat, are required.

For unbonded bars under dynamic loading, the connections shall withstand at least 500,000 cycles from 60 percent to 66 percent MUTS followed by at least 50 cycles between 40 percent MUTS and 80 percent MUTS. A minimum of three tests, each from a different heat, are required.

The Contractor shall supply a Manufacturer's Certificate of Compliance in accordance with Section 1-06.3 for each bar. The Contractor shall supply a Manufacturer's Certificate of Compliance in accordance with Section 1-06.3 for all nuts and couplers confirming compliance with the specified strength requirement.

For each heat of steel for high-strength steel bar, the Contractor shall submit two samples, each not less than 5-feet long, to the Engineer for testing.

9-08 PAINTS

9-08.1 Raw Materials

The acceptance of particular lots of raw materials shall in no way obligate the Engineer to accept lots of finished paint that do not conform to the requirements of these Specifications. When not specifically detailed, the raw materials shall meet the requirements of the applicable Federal Specification in effect at the time of manufacture. Products not covered by State or Federal Specifications shall be of top quality, meeting prevailing commercial standards. Raw materials for paints shall conform to the requirements of the specifications listed below.

Alkyd resin solution, Federal TT-R-266, Type I or Type II.

Aluminum paste, ASTM D 962, Type 2, Class B. Paints made with the paste shall be smooth and highly lustrous.

Anti-skinning agent shall have no deleterious effect on the drying time of the finished paint. It shall effectively prevent skinning when added in the amounts specified in each formula and tested in accordance with Federal Test Std. No. 141a, Method 3021.

Aromatic petroleum thinner — water white low aniline petroleum solvent Kauri-Butanol value ..... 70 (min.)

Barium sulfate pigment, ASTM D 602.

Chrome oxide green, ASTM D 263. The tinting properties shall be such that the standard color of the formulas using chrome oxide green can be produced without departing from the limits of composition given in those formulas.

Chrome yellow pigment and paste, ASTM D 211, Type III.

Fibrous magnesium silicate (talc), ASTM D 605.

Lampblack pigment and paste, ASTM D 209.

Liquid drier, ASTM D 600.

Mineral spirits, ASTM D 235.

Raw linseed oil, ASTM D 234.

Red iron oxide pigment, ASTM D3721, D3722 & D3724.

Silica shall be finely ground amorphous or crystalline material. It shall have a maximum oil absorption of 50 when tested in accordance with ASTM D 281.

Soya lecithin shall be pure.

Spar varnish, Federal TT-V-119.

Titanium pigments, ASTM D 476. Titanium dioxide for use in exterior white paints shall conform to Type II. Titanium pigments used in tinted paints and enamels shall be exterior chalk resistant, Type III.

Turpentine shall be gum spirits of turpentine, ASTM D 13.

Yellow iron oxide, hydrated, ASTM D 768.

Zinc oxide pigment and paste, ASTM D 79.

Zinc yellow (zinc chromate), ASTM D 478.

Raw materials not specifically covered shall meet current Federal specifications for said material.

9-08.2 Paint Formulas — General

All paints shall be made from materials meeting the requirements specified in Section 9-08.1. The paint shall be made in accordance with the following formulas and shall meet the requirements set forth above as well as the special requirements set forth for each formula. The formulas are stated in terms of dry pigment. Each formula shall contain the specified raw materials which shall be proportioned to give the compositions in percentages by weight or parts by weight, as shown in the formulas that follow.

Formula A-5-61 — Vinyl Pretreatment

The primer shall meet the requirements of Federal Specification MIL-P-15328B or MIL-P-15328C, Primer Pretreatment (Formula 117B for Metals).

Vinyl Wash Primer shall be mixed by adding 1 volume of acid component (diluent) to 4 volumes of resin component (base solution) slowly and with constant stirring. The material shall be used within 8 hours of mixing. The wash primer coat shall be spray applied to all surfaces at a coverage rate of 250 to 300 square feet per gallon to yield a dry film of 0.5 to 0.9 mils thickness. If necessary to maintain a wet spray, additional thinning with normal Butanol or 99 percent Isopropanol will be allowed. Acid component above the required amount shall not be used for thinning. A drying time of one hour is required before recoating.

1. Butanol shall meet Federal Specification TT-B-846b Butyl Alcohol; Normal.
2. Isopropanol (99 percent) shall conform to ASTM D 770 Isopropyl Alcohol.

Formula A-9-73 — Galvanizing Repair Paint, High Zinc Dust Content

The galvanizing repair paint shall meet the requirements of Federal Specification MIL-P-21035 (Ships) Paint, High Zinc Dust Content, Galvanizing Repair.

Formula C-6-90 — Green Phenolic Finish Coat for Steel

Zinc chromate (dry pigment)	13.8 parts
Chrome green oxide (dry pigment)	16.1 parts
Titanium dioxide (dry pigment)	16.7 parts
Yellow iron oxide (dry pigment)	1.3 parts
Fibrous magnesium silicate (dry pigment)	5.0 parts
Aluminum stearate (dry pigment)	0.2 parts
Spar varnish	22.1 parts
Raw linseed oil	21.4 parts
Driers	1.0 parts
Anti-skinning agent	0.1 parts
Mineral spirits	2.3 parts
Weight per gallon (minimum)	12.5 lbs.
Viscosity at 70ºF	80 ± 8 K.U.
Grind (minimum)	6
Set to touch	4 hours
Dry hard	18 hours
Sag Index	7 min.

Test Requirements: Prior to shipment.
Viscosity Adjustment: Mineral spirits to be added at the factory to achieve the specified viscosity.

The proportions of tinting pigments may be varied to achieve the desired color. The color of the paint when dry must match the color of a standard C-6-90 color chip. Additional tinting pigments may be required.

Formula C-9-90 — Phenolic Finish Coat for Steel

Zinc Oxide (dry pigment)	10.0 parts
Titanium Dioxide (dry pigment)	21.0 parts
Fibrous Magnesium Silicate (dry pigment)	3.2 parts
Barium Sulfate (dry pigment)	12.8 parts
Tinting Pigments	5.9 parts
Treated Bentonite Clay (dry pigment)	0.2 parts
Anti-Sag Agent	1.9 parts
Raw Linseed Oil	12.6 parts
Spar Varnish	29.0 parts
Anti-Skin Agent	0.1 parts
Driers	1.0 parts
Mineral Spirits	1.8 parts
Xylene	0.5 parts
Weight per gallon (minimum)	12.3 lbs.
Viscosity 70ºF	80 ± 8 K.U.
Dry Hard (maximum)	18 hours
Set to Touch (maximum)	4 hours
Grind (N.S.) (minimum)	5
Sag Index (minimum)	4
Total Solids by Weight	80 ± 5%

Test Requirements: Prior to shipment.

Adjustments for tinting pigments and talc, solvents and chemical additives shall be made at the factory to achieve the desired color and physical characteristics. A fungicide, N-(Trichloromethylthio) phthalimide shall be added at the rate of 3 pounds per 100 gallons.

C-10-83 — Vinyl Finish Coat

Vinyl Finish Coat shall conform to the following specifications:

Pigment (12 Percent Minimum by Mass)

A combination of titanium dioxide and colored pigments or a combination of colored pigments such that the resultant paint when dry matches the color sample available at the Project Engineer's office.

Vehicle (88 Percent Maximum by Mass)

Vinyl Resin Type II[1]	9.1 parts
Vinyl Resin Type III[2]	9.1 parts
Tricresyl Phosphate	3.4 parts
Methyl Isobutyl Ketone	39.2 parts
Toluene	39.2 parts
	100.0

[1]Vinyl Resin Type II shall be hydroxyl containing vinyl chloride-acetate copolymer. It shall contain 89.5 to 91.5 percent (by weight) vinyl chloride, 2.0 to 5.5 percent vinyl acetate and 5.3 to 7.0 percent vinyl alcohol. It shall produce results in the specified formulations equal to the Bakelite Corporation Vinylite resin VAGH.

[2]Vinyl Resin Type III shall be a vinyl chloride-acetate co-polymer of medium average molecular weight and shall contain 85 to 88 percent vinyl chloride and 12 to 15 percent vinyl acetate by weight. It shall produce in the specified formulations results equal to Bakelite Corporation Vinylite resin VYHH.

Lampblack shall be ground in the Vinyl Finish Coat vehicle to yield a smooth well ground paint, Black Vinyl Tinting Paste, satisfactory for tinting either the Vinyl-Red Lead Primer or Vinyl Finish Coat.

The Vinyl Finish Coat and Vinyl Tinting Paste shall be ground to a fineness of not less than 5 when testing in accordance with Federal Test Method Standard No. 141b, Method 4411.1.

Vinyl Thinner shall be composed of the following materials:

Toluene	90 percent by volume
Methyl Isobutyl Ketone	10 percent by volume

The paints as received will require thinning with from 20 to 35 percent by volume of Vinyl Thinner to maintain a wet spray.

Formula D-1-57 — Aluminum Paint

Aluminum paste Type 2 Class B	2.0 lbs.
Spar Varnish	1.0 gallon

Aluminum paint shall be mixed on the job site, and only enough for one day shall be mixed at a time. The weighed amount of paste shall be placed in a suitable mixing container and the measured volume of vehicle then poured over it. The paste shall be incorporated by vigorous stirring with a paddle.

Test Requirements: Prior to mixing.

Formula D-4-57 — Black Enamel

The enamel shall meet the requirements of Federal TT-E-529 Black Enamel, Synthetic, Semi Gloss.

Test Requirements: This enamel will be sampled and tested in the ready-mixed form.

Formula D-5-83 — White Guardrail Paint (Alkyd Vehicle)

Titanium dioxide (dry pigment)	28.1 parts
Zinc oxide (dry pigment)	10.9 parts
Fibrous magnesium silicate (dry pigment)	4.3 parts
Aluminum stearate (dry pigment)	0.5 parts
Alkyd vehicle	37.0 parts
24% lead naphthenate drier	0.4 parts
6% Cobalt naphthenate drier	0.2 parts
6% Manganese naphthenate drier	0.2 parts
Anti-skinning agent	0.2 parts
Mineral spirits	18.2 parts
Weight per gallon (minimum)	11.0 lbs.
Viscosity at 70ºF	80-90 K.U.
Nonvolatile content (minimum)	70.2%
Grind (minimum)	4
Hiding power (maximum scale reading)	30
Set to touch	4 hours
Dry hard	18 hours
Sag Index	7 min.

Test Requirements: Prior to shipment.
Viscosity Adjustment: Mineral spirits will be added at the factory to achieve the specified viscosity.

This formula is to be used over primed or previously painted surfaces.

Formula E-1-57 — White for Wood Structures

The material shall conform to Federal TT-P-102, Class A.

Test Requirements: This paint will be sampled and tested in the ready-mixed form.

Primer: Turpentine may be added to the above paint in quantities not to exceed 1½ pints per gallon of paint for use as a primer.

Formula E-2-62 — Primer for Wood

The primer shall be a ready mixed priming paint for use over unpainted wood surfaces. It shall meet the requirements of Federal Specification TT-P-25 Primer, Paint, Exterior.

Test Requirements: This paint shall be sampled and tested in the ready-mixed form.

Formula F-3-64 — Orange Equipment Enamel

The enamel shall meet the requirements for Enamel, Alkyd, Gloss, Federal Specification TT-E-489, except that the Sag Index shall be seven minimum. The color, when dry, shall match that of Federal Standard No. 595, color 12246.

Test Requirements: When manufactured on Contract or Purchase Order for maintenance use, the enamel will be sampled and tested in the ready-mix form. No factory inspection will be required; however, a 1 pint sample representing the batch must be submitted to the Materials Laboratory for approval before use.

For factory application to individual items of new equipment, samples of the enamel will not be required; however, the equipment manufacturer must match the color and certify the quality of enamel used.

Formula H-1-83 — Primer for Concrete

Titanium dioxide	5.0 parts
Calcium carbonate	19.7 parts
Fibrous magnesium silicate	6.8 parts
Silica	6.8 parts
Spar varnish	52.3 parts
Mineral spirits	9.4 parts
Weight per gallon (minimum)	9.8 lbs.
Drying time (for testing purposes only)	18 hours
Viscosity at 70ºF	65-75 K.U.

Consistency: The paint shall not thicken after manufacture to an extent sufficient to impair its brushing qualities.

Test Requirements: Prior to shipment.

Formula K-1-83 — Exterior Acrylic Latex Paint-White

This paint shall meet the requirements of Federal Specification TT-P-19, Paint, Acrylic Emulsion, Exterior, except that the viscosity shall be 75-85 K.U.

This paint may be used self-primed in multiple coats over salts treated wood and on interior and exterior masonry surfaces.

Test Requirements: This paint will be sampled and tested in the ready-mixed form.

Formula K-2-83 — Traffic Signal Yellow Enamel

Traffic signal yellow enamel shall meet the provision of Federal Specification TT-E-489 — Enamel, Alkyd, Gloss — and shall match the color of "Standard Interstate Yellow."

Formula A-11-99 — Primer, Zinc Filled Single Component, Moisture-Cured Polyurethane

Zinc rich primer shall meet the following requirements:

Vehicle Type: Moisture-cured polyurethane

Pigment Content: 80% minimum zinc by weight in dry film.

Volume Solids: 60% plus or minus 3%.

Minimum wt./gal. 22.0 pounds.

Formula B-11-99 — Intermediate and Stripe Coat, Single Component, Moisture Cured Polyurethane

Vehicle Type: Moisture-cured polyurethane

Pigment: A minimum of 3.0 lbs. of micaceous iron oxide per gallon.

Intermediate and any stripe coat shall meet the following requirements:

Minimum volume solids 50%.

A minimum of 3.0 lbs./gal. of micaceous iron oxide.

The intermediate coating must be certified by the manufacturer to be able to be recoated by the top coat in a minimum of 4 days.

When used as a universal primer on previously painted surfaces, the intermediate coat must not lift the undercoats and must adhere well to the painted surface, to bare steel, aluminum, or galvanized surfaces.

Formula C-11-99 — Top Coat Single Component, Moisture Cured Polyurethane

Vehicle Type: Moisture-cured aliphatic polyurethane

Color: Match Federal Standard 595a

The Top Coat shall meet the following requirements:

The resin must be an aliphatic urethane.

Minimum volume solids 50%.

The top coat shall be a gloss.

Any evidence of aromatic rings, or more than 0.7% free isocyanate monomer as a percent of total solids will not be accepted.

9-08.3 Inspection Requirements General

The manufacturer shall notify the Engineer of the date on which manufacture will be started, and the Engineer shall have the right to inspect all details of the manufacturing process.

Quantities of 20 gallons or less of the above formulas will be accepted without inspection upon the manufacturer's notarized certificate. This certificate shall contain a statement by the manufacturer to the effect that the material meets the formula specification, and shall include a list of materials and quantities used. One copy of the certificate shall accompany the paint when shipped and one copy with a sample of the paint shall be sent to the Materials Laboratory. The paint may be used at once without further release from the Materials Laboratory.

9-08.4 Process of Manufacture

The following process of manufacture shall be used for each paint except aluminum paint. Pigments shall be ground thoroughly in appropriate portions of the specified vehicle to form a paste meeting the requirements set forth in Section 9-08.4(6).

The grinding shall be done in a mill approved by the Engineer. The use of the "colloid" type of mill will not be approved. Weighed quantities of the paste and weighed or measured quantities of the vehicles shall then be mixed thoroughly and strained, if necessary, to form a paint free from skins, lumps, and foreign materials.

9-08.4(1) Viscosity Adjustment

The volatile thinner content of the paint shall be adjusted at the factory to meet the required viscosity, but in no case shall the resultant weight per gallon and nonvolatile content of the paint be below that specified in the formula.

9-08.4(2) Weight Variations

The weight per gallon of the paint in any lot shall not be less than that stated in the formula. A "lot" as used in this section shall be the quantity of paint ground at one time by any one mill.

9-08.4(3) Drying Time and Quantity of Drier

The paint shall dry within the length of time stated in each formula but shall not contain sufficient quantities of drier to cause the paint to dry to a nonuniform or nonelastic film. The manufacturer will be permitted to vary the quantity of drier given in the formula sufficiently to accomplish the above results.

9-08.4(4) Working Properties

The paint shall contain no caked material that cannot be broken up readily by stirring. When applied to a clean vertical surface, the paint shall dry without running, streaking, or sagging.

9-08.4(5) Storage Properties

Paints manufactured under these Specifications shall show no skin over the surface after 48 hours in a partially filled container, when tested as outlined in Federal Test Method Standard No. 141. A slight amount of skin or gel formation where the surface of the paint meets the side of the container may be disregarded. Variable percentages of anti-skinning agents are shown in those formulas set forth above that are susceptible to undesirable skin formation. The manufacturer will be allowed to vary the amount of anti-skinning agent given in the formulas provided the above results are accomplished and provided the paint does not dry to a nonuniform or nonelastic film.

9-08.4(6) Fineness of Grinding

The paint shall be ground so that all particles of pigment will be dispersed and be coated with vehicle, and the residue on a 325 sieve will not exceed 1 percent by weight of the pigment.

9-08.4(7) Standard Colors

When the paint is required to match a standard color, the manufacturer may obtain a sample of the required color without cost upon application to the Materials Laboratory, P.O. Box 47365, Olympia, Washington 98504-7365.

9-08.4(8) Containers

Each container shall be filled with paint and sealed airtight. Each container shall be filled with the amount of paint required to yield the specified quantity when measured at 70ºF.

All paint shall be shipped in new suitable containers having a capacity not greater than 5 gallons. Each container shall be marked with a suitable number to identify the particular batch from which it was filled.

9-08.5 Test Methods

As set forth in Section 9-08.2, all paints shall meet the special requirements set forth for each formula. The test methods used to check those special requirements shall be as specified in the Washington State Department of Transportation *Materials Manual* or the corresponding test method covered by Federal Test Method Standard No. 141. When test methods are not covered by the above, applicable ASTM methods shall be followed.

9-08.6 Shipping

Except for lots of paint in quantities of 20 gallons or less which are accepted upon the manufacturer's certificate, the manufacturer shall not ship any lot of paint until the paint has been tested and released by the Washington State Department of Transportation State Materials Laboratory. This release will not constitute final acceptance of the paint. Final acceptance will be based on inspection or testing of job site samples as determined by the Engineer.

9-08.7 Field Samples

Because of the volatility of the solvents used in the paint, the upper limit on viscosity shall be waived on all paint samples taken in the field.

9-09 TIMBER AND LUMBER

9-09.1 General Requirements

All timber and lumber for structures shall be Douglas Fir-Larch, unless specified otherwise in the contract. The allowable species of timber and lumber for guardrail posts, signposts, and mileposts shall be Douglas Fir-Larch or Hem Fir. Timber and lumber for sawed fence posts and mailbox posts shall be Western Red Cedar, Douglas Fir-Larch, or Hem Fir.

9-09.2 Grade Requirements

Timber and lumber shall conform to the grades and usage listed below. Grades shall be determined by the current standards of the West Coast Lumber Inspection Bureau (WCLIB) or the Western Wood Products Association (WWPA).

Structures

Timber and lumber, unless specified otherwise in the contract, shall conform to the following:

Materials 2″ to 4″ nominal thick, 5″ nominal and wider (Structural Joists and Planks)	No. 1 and better, grade (Section 123-b of WCLIB) or (Section 62.11 of WWPA)
Materials 5″ nominal and thicker (Beams and Stringers)	No. 1 and better, grade (Section 130-b of WCLIB) or (Section 70.11 of WWPA)

Timber lagging for soldier pile walls shall be Douglas Fir-Larch, grade No. 2 or better or Hem-Fir No. 1.

Guardrail Posts

Timber and lumber for guardrail posts (classified as Posts and Timbers) shall conform to the species and grades listed below.

Douglas Fir	No. 1 and better, grade (Section 131-b WCLIB) or (Section 80.11 WWPA)
Hem Fir	Select Structural, grade (Section 131-a WCLIB) or (Section 80.10 WWPA)

Sign Posts, Mileposts, Sawed Fence Posts, and Mailbox Posts

Sign posts, mileposts, sawed fence posts, and mailbox posts shall conform to the grades shown below.

4 × 4	Construction grade (Light Framing, Section 122-b WCLIB) or (Section 40.11 WWPA)
4 × 6	No. 1 and better, grade (Structural Joists and Planks, Section 123-b WCLIB) or (Section 62.11 WWPA)
6 × 6, 6 × 8, 8 × 10	No. 1 and better, grade (Posts and Timbers, Section 131-b WCLIB) or (Section 80.11 WWPA)
6 × 10, 6 × 12	No. 1 and better, grade (Beams and Stringers, Section 130-b WCLIB) or (Section 70.11 WWPA)

9-09.2(1) Surfacing and Seasoning

All timber and lumber shall be sized as indicated in the plans.

All timber and lumber to be painted shall be surfaced on all sides. All timber and lumber to be painted shall be thoroughly air or kiln dried to an equilibrium moisture content and shall be stored in such a manner as to remain in a thoroughly dry condition until placed into the work.

9-09.2(2) Vacant

9-09.2(3) Inspection

Timber and lumber must be marked with a certified lumber grade stamp provided by one of the following agencies:

West Coast Lumber Inspection Bureau (WCLIB)

Western Wood Products Association (WWPA)

Pacific Lumber Inspection Bureau (PLIB)

Any lumber grading bureau certified by the American Lumber Standards Committee

For Structures:

A grading certificate must accompany each order of timber and lumber for use in structures as specified in Section 9-09.2. The certificate shall be issued by either the grading bureau whose stamp is shown on the material, or by the lumber mill, which must be under the supervision of one of the grading bureaus listed above. The certificate shall include the following:

Name of the mill performing the grading

The grading rules being used

Name of the person doing the grading with current certification

Signature of a responsible mill official

Date the lumber was graded at the mill

Grade, dimensions, and quantity of the timber or lumber

When the material is delivered to the project, the Engineer shall check the order for the appropriate grade stamp. The invoice and grading certificate accompanying the order must be accurate and complete with the information listed above. The grading certificate and grade markings shall not constitute final acceptance of the material. The Engineer may reject any or all of the timber or lumber that does not comply with the specifications or has been damaged during shipping or upon delivery.

For Guardrail Posts and Blocks, Sign Posts, Mileposts, Sawed Fence Posts, and Mailbox Posts:

When the material is delivered to the project, the Engineer shall check the order for the appropriate grade stamp. The grade markings shall not constitute final acceptance of the material. The Engineer may reject any or all of the timber or lumber that does not comply with the specifications or has been damaged during shipping or upon delivery.

9-09.3 Preservative Treatment

9-09.3(1) General Requirements

All timber and lumber requiring preservative treatment shall be treated in accordance with AASHTO M 133. As specified by AASHTO M 133, the American Wood-Preservers' Association (AWPA) standards shall govern the specifications. These specifications include: storing and curing the timber and lumber, the wood preservatives, the preservative treatment process, documenting the results of the treatment, inspection, testing, and the identification of properly treated timber. Unless otherwise specified in the contract, all timber and lumber shall be treated in accordance with Section C-14 of the latest addition of the AWPA standards.

All cutting, boring, chamfering, routing, surfacing, and trimming shall be done prior to treating. Any field drilling or cutoffs shall be treated by two liberal applications of a compatible preservative. The applications shall be in accordance with the requirements of AWPA Standard M-4 entitled, "Standard for the Care of Pressured Treated Wood Products".

All charges shall consist of pieces of the same species that are similar in form, size, moisture content, and receptivity to treatment. The pieces in the charge shall be separated to ensure contact of treating medium with all surfaces. The method of determining the retention of the preservatives shall be by assay.

As specified in the contract, all orders of treated timber and lumber will be stamped "WSDOT Approved for Shipment" or accompanied by a Certificate of Treatment record. The Certificate of Treatment shall include the following information:

Name and location of the wood preserving company

Customer identification

Date of treatment and charge number

Type of chemical used and amount of retention

Treating process and identification of the specification used

Description of material that was treated

Signature of a responsible plant official

In addition to the Certificate of Treatment, all orders of treated timber or lumber that are not stamped "WSDOT Approved for Shipment", shall be accompanied by a Grading Certificate in accordance with Section 9-09.2(3). Such certification or approved for shipment tag shall not constitute final acceptance of the material. The Engineer may reject any or all of the timber or lumber that does not comply with the specifications or has been damaged during prolonged storage, shipping, or upon delivery.

All timber and lumber to be used in aquatic environments, unless specified otherwise in the contract, shall be chemically treated using Best Management Practices (BMPs). The producer of the chemically treated products shall supply a written certification that the BMPs were utilized, including a description and appropriate documentation of the BMPs used. This information may be included on the Certificate of Treatment record.

9-10 PILING

9-10.1 Timber Piling

Timber piling shall be untreated or treated with the preservatives specified in the Plans and completely described in Section 9-09.3.

Timber piles shall have the following limiting diameters:

Length in Feet	Min. Butt Dia. 3-feet Above Butt in inches	Max. Butt Dia. 3-feet Above Butt in inches	Min. Tip Dia. in inches
Under 40	12	20	7
40-54	12	20	7
55-74	13	20	7
Over 74	14	20	7

Timber piles shall be strapped with at least three straps: one approximately 18-inches from the butt, one approximately 24-inches from the butt, and one approximately 12-inches from the tip. Additional straps shall be provided at approximately 15-foot centers between the butt and tip. Strapping shall encircle the pile once and be tensioned as tightly as possible. Straps shall be 1¼-inches wide, 0.31-inch thick, cold rolled, fully heat treated, high tensile strapping, painted, and waxed, with an ultimate tensile strength of 5,100 pounds. The seal shall be 2¼-inches long, 20 gage, crimped with a notch type sealer to furnish a joint yielding 80 percent of the strap tensile strength. Treated timber piles shall be strapped after treatment.

9-10.1(1) Untreated Piling

Except where specifically provided otherwise, untreated timber piling shall be Douglas Fir, Western Red Cedar, or Larch. Piling for foundations shall be Douglas Fir. Piling shall be cut from sound, live trees and shall contain no unsound knots. Sound knots will be permitted, provided the diameter of the knot does not exceed 4-inches, or $^1/_3$ of the small diameter of the pile at the point where they occur, whichever is smaller. Any defect or combination of defects which will impair the strength of the pile more than the maximum allowable knot will not be permitted.

Piling shall be cut above the butt swell and shall have a uniform taper from butt to tip. A line drawn from the center of the tip to the center of the butt shall not fall outside the center of the pile at any point more than one percent of the length of the pile. A spiral grain or twist in excess of $^1/_4$ turn in 10-feet of length will be cause for rejection.

Untreated timber trestle piling shall have an average of at least five annual rings per inch measured radially over a distance of 3-inches at the butt, beginning at a point 3½-inches from the heart. At least 9-inches of heartwood shall show at the butt.

Ring count requirements for untreated timber foundation piling and detour trestle piling will be waived.

9-10.1(2) Creosote Treated Piling

For creosote treated piling, Douglas Fir timber shall be used. All other requirements shall be the same as for untreated piling, except that the ring count requirement will be waived.

9-10.1(3) Timber Composite Piling

Timber composite piling shall consist of a pile made up of two timber sections. The lower section shall be untreated, and the upper section shall be creosote treated.

The treated and untreated sections of timber composite pile shall meet the respective requirements specified above for full length of treated and untreated timber piling.

9-10.1(4) Peeling

Untreated and creosote treated piles shall be peeled by removing all of the rough bark and at least 80 percent of the inner bark. No strip of inner bark remaining on the pile shall be over ¾-inch wide or over 8-inches long, and there shall be at least 1-inch of clean wood surface between any two such strips. Not less than 80 percent of the surface on any circumference shall be clean wood. All knots shall be trimmed close to the body of the pile.

9-10.2 Concrete Piling

9-10.2(1) Concrete

Cement meeting the requirements of Section 9-01 shall be used in all precast concrete piles.

The concrete for precast-prestressed piles shall conform to the requirements of Section 9-19.1. The concrete for prestressed piles shall have a minimum compressive strength of 6,000 psi at the age of 28 days. The minimum compressive strength of concrete at the transfer of prestress shall be 3,300 psi.

The concrete for other precast piles shall be Class 4000. Mixing, transporting, and placing concrete shall be in accordance with the provisions of Section 6-02.3.

The Contractor shall mold and test a sufficient number of concrete test cylinders to determine the strength of the concrete as required by the specifications. Under the surveillance of the Engineer, the test cylinders shall be molded, cured, and tested in accordance with the procedures established by the State Materials Laboratory.

In the event that a sufficient number of concrete test cylinders are not molded to satisfy all testing required on any one pile, cores measuring 4-inches in diameter by 5-inches in height shall be taken and tested by the Contractor. If the strength of the core meets the required compressive strength of the concrete, the pile may be accepted. The coring and testing of the core shall be done under the surveillance of the Engineer.

9-10.2(2) Reinforcement

Reinforcement shall meet the requirements of .

9-10.3 Cast-in-Place Concrete Piling

Reinforcement for cast-in-place concrete piles shall conform to the requirements of AASHTO M 31 Grade 40 or Grade 60.

9-10.4 Steel Pile Tips and Shoes

Steel pile tips and shoes shall be fabricated of cast steel conforming to ASTM A 148 Grade 60-90 [620-415] or ASTM A 27 Grade 65-35 [450-240] and be free from any obvious defects. Pile tips shall be accompanied by a mill test report stating the chemical and physical properties (tensile and yield) of the steel.

9-10.5 Steel Piling

The material for steel piling and pile splices shall conform to ASTM A 36 or ASTM A 992, except the material for steel pipe piling and splices shall conform to the requirements of ASTM A 252, Grade 2. Steel soldier piles, and associated steel bars and plates, shall conform to ASTM A 36 or ASTM A 992, except as otherwise noted in the Plans. All steel piling may be accepted by the Engineer based on the Manufacturer's Certification of Compliance.

9-11 WATERPROOFING

9-11.1 Asphalt for Waterproofing

Asphalt for waterproofing shall conform to the requirements of ASTM D 312, Type 4.

The material used as primer shall conform to the requirements of ASTM D 41, Primer for Use with Asphalt in Dampproofing and Waterproofing.

Acceptance shall be as provided in Section 9-02.2(1).

9-11.2 Waterproofing Fabric

Waterproofing fabric shall be a saturated cotton fabric meeting the requirements of ASTM D 173, Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing.

9-11.3 Portland Cement Mortar

Portland cement and sand for the mortar protection course shall conform to the following requirements:

Portland Cement	Section 9-01
Sand	Section 9-03

9-12 MASONRY UNITS

9-12.1 Concrete Blocks

Concrete blocks for manholes and catch basins shall conform to the requirements of ASTM C 139.

Concrete blocks for building construction shall conform to the requirements of ASTM C 90.

9-12.2 Concrete Brick

Concrete brick shall conform to the requirements of ASTM C 55.

9-12.3 Vacant

9-12.4 Precast Concrete Manholes

Precast concrete manholes shall meet the requirements of AASHTO M 199.

The joints may be the tongue and groove type or the shiplap type, sufficiently deep to prevent lateral displacement.

Manufacturers may reinforce the concrete mix with synthetic fibers as an alternate to conventional secondary reinforcement in 48-inch diameter by 3-foot high eccentric or concentric cone sections. The synthetic fiber, either nylon multifilament fibers or polypropylene fibrillated fibers, shall meet the requirements of ASTM C 1116 , Section 4.1.3 and Note 3 and ICC ES AC 32, Sections 4.1.1 and 4.1.2. Synthetic fibers shall be added at a rate of 1.0 pound of Nylon Multifilament fibers per cubic yard of concrete or 1.5 pounds of Polypropylene Fibrillated fibers per cubic yard of concrete and shall be thoroughly mixed with the concrete before placement in the forms. The synthetic fibers shall be a minimum of 0.75-inches and a maximum of 2-inches in length. A minimum of two hoops of W2 wire shall be placed in the 48-inch end of each cone. No steel is required in the remainder of the cone. Precast concrete units shall be furnished with knockouts or cutouts.

9-12.5 Precast Concrete Catch Basins

Precast concrete catch basins shall conform to the requirements of Section 9-12.4, except that the dimensions shall be as set forth in the Standard Plan.

As an alternate, Type 1, Type 1L and Type 1P, Catch Basins may be fabricated using synthetic fiber reinforcement, either nylon multifilament fibers or polypropylene fibrillated fibers, meeting the requirements of ASTM C 1116 Section 4.1.3 and Note 3 and ICC ES AC 32, Sections 4.1.1 and 4.1.2. Synthetic fibers shall be added at the rate of 1.0 pound of Nylon Multifilament fibers per cubic yard of concrete or 1.5 pounds of Polypropylene Fibrillated fibers per cubic yard of concrete, and shall be thoroughly mixed with the concrete before placement. A minimum amount of steel reinforcement shall be used to reinforce the area around the knockouts. Steel reinforcing shall consist of a No. 3 horizontal hoop reinforcing bar located above the knockouts, and a No. 3 vertical reinforcing bar in each corner, extending a minimum of 18-inches below the top surface of the catch basin.

Knockouts or cutouts may be placed on all four sides and may be round or D shaped.

9-12.6 Precast Concrete Inlets

Precast concrete inlets shall conform to the requirements of Section 9-12.4 except that the dimensions shall be as set forth in the Standard Plan.

9-12.7 Precast Concrete Drywells

Precast concrete drywells shall meet the requirements of Section 9-12.4. Seepage port size and shape may vary per manufacturer. Each seepage port shall provide a minimum of 1 square inch and a maximum of 7 square inches for round openings and 13 square inches for rectangular openings. The ports shall be uniformity spaced with at least one port per 8-inches of drywell height and 15-inches of drywell circumference.

9-13 RIPRAP, QUARRY SPALLS, SLOPE PROTECTION, AND ROCK WALLS

Riprap shall consist of broken stone, broken concrete rubble, or concrete in sacks. Quarry spalls shall consist of broken stone or broken concrete rubble. Riprap and quarry spalls consisting of broken stone or concrete rubble shall be free from segregation, seams, cracks, and other defects tending to destroy its resistance to weather and shall conform to the following requirements for quality.

Degradation Factor	15 minimum
Los Angeles Wear, 500 Rev.	50% maximum
Specific Gravity	2.55 minimum

9-13.1 Loose Riprap

Loose riprap shall be free of rock fines, soil, or other extraneous material.

Should the riprap contain insufficient spalls, as defined in Section 9-13.6, the Contractor shall furnish and place supplementary spall material from a source approved by the Engineer, at the Contractor's expense.

The grading of the riprap shall be determined by the Engineer by visual inspection of the load before it is dumped into place, or, if so ordered by the Engineer, by dumping individual loads on a flat surface and sorting and measuring the individual rocks contained in the load.

9-13.1(1) Heavy Loose Riprap

Heavy loose riprap shall meet the following requirements for grading:

	Minimum Size	Maximum Size
40% to 90%	1 ton ($^1/_2$ cubic yd.)	
70% to 90%	300 lbs. (2 cu. ft.)	
10% to 30%	3-inch	50 lbs. (spalls)

9-13.1(2) Light Loose Riprap

Light loose riprap shall meet the following requirements for grading:

	Size Range	Maximum Size
20% to 90%	300 lbs. to 1 ton (2 cu. ft. to $^1/_2$ cu. yd.)	
15% to 80%	50 lbs. to 1 ton ($^1/_3$ cu. ft. to $^1/_2$ cu. yd.)	
10% to 20%	3-inch	50 lbs. (spalls)

9-13.2 Hand Placed Riprap

Hand placed riprap shall be as nearly rectangular as possible, 60 percent shall have a volume of not less than 1 cubic foot. No stone shall be used which is less than 6-inches thick, nor which does not extend through the wall.

9-13.3 Sack Riprap

Sack riprap shall consist of concrete placed in sacks made of at least 10-ounce burlap and having a capacity of approximately 2.5 cubic feet. Each sack shall be filled

with approximately 1 cubic foot of concrete having a consistency in conformance with Section 6-02.3(4)C for nonvibrated concrete.

Concrete for sack riprap exposed to fresh water and salt water shall be Class 3000 as specified in Section 6-02.3.

The cement and fine and coarse aggregates shall conform to the requirements for cement and fine and coarse aggregate of Sections 9-01 and 9-03.1, respectively.

9-13.4 Vacant

9-13.5 Concrete Slope Protection

Concrete slope protection shall consist of reinforced Portland cement concrete poured or pneumatically placed upon the slope with a rustication joint pattern or semi-open concrete masonry units placed upon the slope closely adjoining each other.

9-13.5(1) Semi-Open Concrete Masonry Units Slope Protection

Precast cement concrete blocks shall conform to the requirements of ASTM C 90.

9-13.5(2) Poured Portland Cement Concrete Slope Protection

Cement concrete for poured concrete slope protection shall be Class 3000 in conformance with Section 6-02.3.

Wire mesh reinforcement shall conform to the provisions of Section 9-07.7.

9-13.5(3) Pneumatically Placed Portland Cement Concrete Slope Protection

Cement: This material shall be Portland cement as specified in Section 9-01.

Aggregate: This material shall meet the requirements for fine aggregate as specified in Section 9-03.1. The moisture content of the fine aggregate at the time of use shall be between 3 percent and 6 percent by weight.

Reinforcement: Wire mesh reinforcement shall conform to the provisions of Section 9-07.7.

Water: Water shall conform to the provisions of Section 9-25.1.

9-13.6 Quarry Spalls

Quarry spalls shall meet the following requirements for grading:

Sieve Size	Percent Passing
8″	100
3″	40 max.
3/4″	10 max.

9-13.7 Rock for Rock Wall

9-13.7(1) Rock for Rock Walls and Chinking Material

Rock for rock walls and chinking material shall be hard, sound and durable material, free from seams, cracks, and other defects tending to destroy its resistance to weather, and shall meet the following minimum requirements:

Test	Test Method	Requirements
Specific Gravity	AASHTO T-85	2.55 min.
LA Wear	AASHTO T-96	50% max.
Degradation	WSDOT 113	15 min.
Absorption	AASHTO T-85	3% max.

Rock for rock wall sizes are approximately as follows:

Rock Size	Rock Weight (lbs.)	Average Dimension (in.)
One Man	50 - 200	12 - 18
Two Man	200 - 700	18 - 28
Three Man	700 - 2,000	28 - 36
Four Man	2,000 - 4,000	36 - 48
Five Man	4,000 - 6,000	48 - 54
Six Man	6,000 - 8,000	54 - 60

Chinking material shall be a minimum of 4-inches average dimension.

9-13.7(2) Backfill for Rock Wall

Backfill for rock walls shall be shot rock ranging in size from a minimum of 2-inches to a maximum of 6-inches.

Acceptance shall be based on visual inspection by the Engineer.

9-14 EROSION CONTROL AND ROADSIDE PLANTING

9-14.1 Soil

9-14.1(1) Topsoil Type A

Topsoil Type A shall be as specified in the Special Provisions.

9-14.1(2) Topsoil Type B

Topsoil Type B shall be native topsoil taken from within the project limits either from the area where roadway excavation is to be performed or from strippings from borrow, pit, or quarry sites, or from other designated sources. The general limits of the material to be utilized for topsoil will be indicated in the Plans or in the Special Provisions. The Engineer will make the final determination of the areas where the most suitable material exists within these general limits. The Contractor shall reserve this material for the specified use. Material for Topsoil Type B shall not be taken from a depth greater than 1-foot from the existing ground unless otherwise designated by the Engineer.

In the production of Topsoil Type B, all vegetative matter, less than 4-feet in height, shall become a part of the topsoil. Prior to topsoil removal, the Contractor shall reduce the native vegetation to a height not exceeding 1-foot. Noxious weeds, as designated by authorized State and County officials, shall not be incorporated in the topsoil, and shall be removed and disposed of as designated elsewhere or as approved by the Engineer.

9-14.1(3) Topsoil Type C

Topsoil Type C shall be native topsoil meeting the requirements of Topsoil Type B but obtained from a source provided by the Contractor outside of the Contracting Agency owned right of way.

9-14.2 Seed

Grasses, legumes, or cover crop seed of the type specified shall conform to the standards for "Certified" grade seed or better as outlined by the State of Washington Department of Agriculture "Rules for Seed Certification," latest edition. Seed shall be furnished in standard containers on which shall be shown the following information:

(1) Common and botanical names of seed,
(2) Lot number,
(3) Net weight,
(4) Percentage of purity,
(5) Percentage of germination (in case of legumes percentage of germination to include hard seed), and Percentage of weed seed content and inert material clearly marked for each kind of seed in accordance with applicable State and Federal laws.

All seed installers must have a business license issued by the Washington State Department of Licensing with a "seed dealer" endorsement. Upon request, the contractor shall furnish the Engineer with copies of the applicable licenses and endorsements.

Upon request, the Contractor shall furnish to the Engineer duplicate copies of a statement signed by the vendor certifying that each lot of seed has been tested by a recognized seed testing laboratory within six months before the date of delivery on the project. Seed which has become wet, moldy, or otherwise damaged in transit or storage will not be accepted.

9-14.3 Fertilizer

Fertilizer shall be a standard commercial grade of organic or inorganic fertilizer of the kind and quality specified. It may be separate or in a mixture containing the percentage of total nitrogen, available phosphoric acid, and water-soluble potash in the amounts specified. All fertilizers shall be furnished in standard unopened containers with weight, name of plant nutrients, and manufacturer's guaranteed statement of analysis clearly marked, all in accordance with State and Federal laws.

Fertilizer shall be supplied in one of the following forms:

(1) A dry free-flowing granular fertilizer, suitable for application by agricultural fertilizer spreader.

(2) A soluble form that will permit complete suspension of insoluble particles in water, suitable for application by power sprayer.

(3) A homogeneous pellet, suitable for application through a ferti-blast gun.

(4) A tablet or other form of controlled release with a minimum of a 6 month release period.

9-14.4 Mulch and Amendments

All amendments shall be delivered to the site in the original, unopened containers bearing the manufacturer's guaranteed chemical analysis and name. In lieu of containers, amendments may be furnished in bulk. A certificate from the manufacturer or supplier indicating the above information shall accompany each delivery. Compost and other organic amendments shall be accompanied with all applicable health certificates and permits.

9-14.4(1) Straw

All straw material shall be in an air dried condition free of noxious weeds and other materials detrimental to plant life. Straw mulch so provided shall be suitable for spreading with mulch blower equipment.

9-14.4(2) Wood Cellulose Fiber

Fiber shall be produced from natural or recycled (pulp) fiber, such as wood chips or similar wood materials, or from newsprint, corrugated cardboard, or a combination of these processed materials. The fibers shall not contain any rock, metal, or plastic. It shall be treated with a nontoxic green dye non toxic to plant or animal life to facilitate inspection of the placement of the material. It shall be manufactured in such a manner that after addition and agitation in slurry tanks with water, the fibers in the material will become uniformly suspended to form a homogenous slurry. When hydraulically sprayed on the ground, the material shall allow the absorption and percolation of moisture.

During the request for approval of the material source process, a letter of certification shall be submitted which certifies that the product contains less than 250 parts per million boron, and shall be otherwise nontoxic to plant or animal life. The organic matter content shall be at least 90 percent on an oven-dry basis as determined by ASTM D 586. The moisture content shall be no more than 15 percent as determined by oven dried weight.

Each package of the cellulose fiber shall be marked by the manufacturer to show the dried weight.

9-14.4(3) Bark or Wood Chips

Bark or wood chip mulch shall be derived from Douglas fir, pine, or hemlock species. It shall be ground so that a minimum of 95 percent of the material will pass through a 1½-inch sieve and no more than 55 percent, by loose volume, will pass through a U.S. No. 4 sieve. The mulch shall not contain resin, tannin, or other compounds in quantities that would be detrimental to plant life.

9-14.4(4) Sawdust

Sawdust mulch shall be free of chips, chunks, and large splinters, and shall not contain resin, tannin, or other compounds in quantities that would be detrimental to plant life.

9-14.4(5) Lime

Agriculture lime shall be of standard manufacture, flour grade or in pelletized form, meeting the requirements of ASTM C-602.

9-14.4(6) Gypsum

Gypsum shall consist of Calcium Sulfate (CaSO42H2O) in a pelletized or granular form. 100% shall pass through a U.S. No. 8 sieve.

9-14.4(7) Tackifier

Tackifiers used as a tie-down for seed and mulch shall be applied in quantities sufficient to equal the retention properties of guar when applied at the rate of 60 pounds per acre for slopes less than 2:1 and 120 pounds per acre for slopes greater than 2:1. Tackifier shall contain no growth or germination inhibiting materials nor significantly reduce infiltration rates. Tackifier shall hydrate in water and readily blend with other slurry materials. Tackifier options include:

Type A — Organic tackifier derived from natural organic plant sources.

Type B — Synthetic tackifier having an MSDS sheet that demonstrates to the satisfaction of Engineer that the product is not harmful to aquatic life.

9-14.4(8) Compost

Compost products shall be the result of the biological degradation and transformation of plant-derived materials under controlled conditions designed to promote aerobic decomposition. Compost shall be stable with regard to oxygen consumption and carbon dioxide generation. Compost shall be mature with regard to its suitability for serving as a soil amendment or an erosion control BMP as defined below. The compost shall have a moisture content that has no visible free water or dust produced when handling the material.

Compost production and quality shall comply with Chapter 173-350 WAC.

Compost products shall meet the following physical criteria:

1. Compost material shall be tested in accordance with the U.S. Composting Council, Testing Methods for the Examination of Compost and Composting (TMECC) Test Method 02.02-B, “Sample Sieving for Aggregate Size Classification”.

   Fine Compost shall meet the following:

	Min.	Max.
Percent passing 2”	100%	
Percent passing 1”	90%	100%
Percent passing ¾”	70%	100%
Percent passing ¼”	40%	75%

Maximum particle length of 6-inches
Coarse Compost shall meet the following:

	Min.	Max.
Percent passing 3”	100%	
Percent passing 1”	90%	100%
Percent passing ¾”	70%	100%
Percent passing ¼”	40%	60%

Maximum particle length of 6-inches

2. The pH shall be between 6.0 and 8.5 when tested in accordance with TMECC 04.11-A, “1:5 Slurry pH”.
3. Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 0.5 percent on a dry weight or volume basis, whichever provides for the least amount of foreign material.
4. Minimum organic matter shall be 40 percent dry weight basis as determined by TMECC 05.07A, “Loss-On-Ignition Organic Matter Method”.
5. Soluble salt contents shall be less than 6.0 mmhos/cm tested in accordance with TMECC 04.10-A, “1:5 Slurry Method, Mass Basis”.
6. Maturity greater than 80% in accordance with TMECC 05.05A, “Germination and Root Elongation”.
7. Stability 8 or below in accordance with TMECC 05.08-B, Carbon Dioxide Evolution Rate”.
8. The compost product must originate a minimum of 65 percent by volume from recycled plant waste as defined in WAC 173-350 as “Type 1 Feedstocks.” A maximum of 35 percent by volume of other approved organic waste and/or biosolids may be substituted for recycled plant waste. The supplier shall provide written verification of feedstock sources.

The compost supplier will test all compost products within 30 calendar days prior to initial application with samples taken from the material stockpiled by the supplier for project use. Samples will be taken using the Seal of Testing Assurance (STA) sample collection protocol. (The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans Memorial Highway, Suite 275, Holbrook, NY 11741 Phone: 631-737-4931). The sample shall be sent to an independent STA Program approved lab. The compost supplier will pay for the test. A copy of the approved independent STA Program laboratory test report shall be submitted to the Contracting Agency prior to initial application of the compost.

Compost not conforming to the above requirements or taken from a source other than those tested and accepted shall be immediately removed from the project and replaced at no cost to the Contracting Agency.

The contractor shall either select a compost supplier from the Qualified Products List, or submit the following information to the Engineer for approval:

1. A Request for Approval of Material Source.
2. A copy of the Solid Waste Handling Permit issued to the supplier by the Jurisdictional Health Department as per WAC 173-350 (Minimum Functional Standards for Solid Waste Handling).
3. The supplier shall verify in writing, and provide lab analyses that the material complies with the processes, testing, and standards specified in WAC 173-350 and these specifications. The analysis shall be performed by an independent STA Program certified laboratory.
4. A list of the feedstock by percentage present in the final compost product.
5. A copy of the producers Seal of Testing Assurance certification as issued by the U.S. Composting Council.

Acceptance will be based upon a satisfactory Test Report from an independent STA program certified laboratory.

9-14.4(9) Bonded Fiber Matrix (BFM)

The BFM shall be a hydraulically-applied blanket/mulch/covering composed of long strand, thermally processed wood fibers and crosslinked, hydro-colloid tackifier. The BFM may require a 24-48 hour curing period to achieve maximum performance. Once cured, the BFM forms an intimate bond with the soil surface to create a continuous, absorbent, flexible erosion resistant blanket that allows for rapid germination and accelerated plant growth.

9-14.4(10) Mechanically-Bonded Fiber Matrix (MBFM)

The MBFM shall be a hydraulically-applied, flexible erosion control blanket/mulch/covering composed of long strand, thermally processed wood fibers, crimped, interlocking fibers and performance enhancing additives. The MBFM shall require no curing period and upon application forms an intimate bond with the soil surface to create a continuous, porous, absorbent and erosion resistant blanket that allows for rapid germination and accelerated plant growth.

9-14.5 Erosion Control Devices

9-14.5(1) Polyacrylamide (PAM)

Polyacrylamide (PAM) products shall meet ANSI/NSF Standard 60 for drinking water treatment with an AMD content not to exceed 0.05%. PAM shall be anionic or non-ionic and shall be linear, and not cross-linked. The minimum average molecular weight shall be greater than 5 Mg/mole. The product shall contain at least 80% active ingredients and have a moisture content not exceeding 10% by weight.

9-14.5(2) Erosion Control Blanket

Organic temporary erosion control blanket shall meet the following requirements:

1. Made of natural plant fibers.
2. Have a minimum weight of 8 oz./sq. yd. and a minimum limiting shear stress of 0.45 lb./sq. ft.
3. Netting, if present, shall be biodegradable or photodegradable.

Permanent erosion control blanket shall meet the following requirements:

1. Consist of UV stabilized[1] fibers, filaments, and netting.
2. Have a minimum weight of 8 oz./sq. yd. and a minimum limiting shear stress of 1.5 lb./sq. ft.

[1]UV stability (minimum 80 percent tensile retained) ASTM D4355 (1,000 hour exposure).

9-14.5(3) Clear Plastic Covering

Clear plastic covering shall meet the requirements of the NIST Voluntary Product Standard, PS 17-69, for polyethylene sheeting having a minimum thickness of 6 mils.

9-14.5(4) Geotextile-Encased Check Dam

The geotextile-encased check dam shall be a urethane foam core encased in geotextile material. The minimum length of the unit shall be 7-feet.

The foam core shall be a minimum of 8-inches in height, and have a minimum base width of 16-inches. The geotextile material shall overhang the foam by at least 6-inches at each end, and shall have apron type flaps that extend a minimum of 24-inches on each side of the foam core. The geotextile material shall meet the requirements for silt fence in Section 9-33.

9-14.5(5) Wattles

Wattles shall consist of cylinders of biodegradable plant material such as straw, coir, or wood shavings encased within biodegradable or photodegradable netting. Netting shall meet the requirements of Section 9-14.5. Rolls shall be at least 6-inches in diameter, unless otherwise specified.

9-14.5(6) Compost Sock

Biodegradable burlap fabric for compost sock and compost wattle shall be clean, evenly woven, and free of encrusted concrete or other contaminating materials and shall be free from cuts, tears, broken or missing yarns and thin, open, or weak places. Fabric for compost sock shall consist of extra heavy weight biodegradable burlap fiber which has not been treated with any type of preservative. Compost for compost socks shall meet the material requirements as specified in Section 9-14.4(8), and shall be compost Type 2.

Wood stakes for compost sock and wattles shall be made from Douglas-Fir, Hemlock, or Pine species. Wood stakes shall be 2-inch by 2-inch nominal dimension and 36-inches in length, unless otherwise indicated in the Plans.

9-14.6 Plant Materials

9-14.6(1) Description

Seedlings are plants grown from cuttings, seeds, tissue culture, or other standard nursery propagation methods. Measurement is by height in 3-inch increments or by age and number of times transplanted.

Whips are bareroot, broadleaf trees, generally unbranched and between 2-feet and 6-feet in height. Measurement is by 1-foot height increments.

Broadleaf trees are branched, over 6-feet in height and measured by caliper and/or height.

Coniferous trees are over 2-feet in height and measured in height and occasionally spread.

Shrubs and ground covers begin to show form characteristic to their normal habit of growth and are measured by height and/or spread.

Container sizes may be specified in addition to other measurements, however, the other measurements shall govern.

Cuttings are live plant material without a previously developed root system. Source plants for cuttings shall be dormant when cuttings are taken. All cuts shall be made with a sharp instrument. Written permission shall be obtained from property owners and provided to the Engineer before cuttings are collected. The Contractor shall collect cuttings in accordance with applicable sensitive area ordinances. For cuttings, the requirement to be nursery grown or held in nursery conditions does not apply. Cuttings include the following forms:

A. Live branch cuttings shall have flexible top growth with terminal buds and may have side branches. The rooting end shall be cut at an approximate 45 degree angle.

B. Live stake cuttings shall have a straight top cut immediately above a bud. The lower, rooting end shall be cut at an approximate 45-degree angle. Live stakes are cut from one to two year old wood. Live stake cuttings shall be cut and installed with the bark intact with no branches or stems attached, and be ½ to 1 $^{1}/_{2}$-inch in diameter.

C. Live pole cuttings shall have a minimum 2-inch diameter and no more than three branches which shall be pruned back to the first bud from the main stem.

D. Rhizomes shall be a prostrate or subterranean stem, usually rooting at the nodes and becoming erect at the apex. Rhizomes shall have a minimum of two growth points.

E. Tubers shall be a thickened and short subterranean branch having numerous buds or eyes.

9-14.6(2) Quality

All plant material furnished shall meet the grades established by the latest edition of the American Standard for Nursery Stock, (ASNS) ANSI Z60.1 shall conform to the size and acceptable conditions as listed in the contract, and shall be free of all foreign plant material.

All plant material shall comply with State and Federal laws with respect to inspection for plant diseases and insect infestation.

Live woody or herbaceous plant material, except cuttings, rhizomes, and tubers, shall be vigorous, well formed, with well developed fibrous root systems, free from dead branches, and from damage caused by an absence or an excess of heat or moisture, insects, disease, mechanical or other causes detrimental to good plant development. Evergreen plants shall be well foliated and of good color. Deciduous trees that have solitary leaders shall have only the lateral branches thinned by pruning. All conifer trees shall have only one leader (growing apex) and one terminal bud, and shall not be sheared or shaped. Trees having a damaged or missing leader, multiple leaders, or Y-crotches shall be rejected.

Root balls of plant materials shall be solidly held together by a fibrous root system and shall be composed only of the soil in which the plant has been actually growing. The ball shall be securely wrapped with jute burlap or other packing material not injurious to the plant life. Root balls shall be free of weed or foreign plant growth.

Plant materials shall be nursery grown stock. Plant material, with the exception of cuttings, gathered from native stands shall be held under nursery conditions for a minimum of one full growing season, shall be free of all foreign plant material, and meet all of the requirements of these Specifications, the Plans, and the Special Provisions.

Container grown plants must be plants transplanted into a container and grown in that container sufficiently long for new fibrous roots to have developed so that the root mass will retain its shape and hold together when removed from the container. Plant material which is root bound, as determined by the Engineer, shall be rejected.

Container sizes for plant material of a larger grade than provided for in the container grown specifications of the ASNS shall be determined by the volume of the root ball specified in the ASNS for the same size plant material.

All bare root plant materials shall have a heavy fibrous root system and must be dormant at the time of planting.

Average height to spread proportions and branching shall be in accordance with the applicable sections, illustrations, and accompanying notes of the ASNS.

Plants specified or identified as “Street Tree Grade” shall be trees with straight trunks, full and symmetrical branching, central leader, and be developed, grown, and propagated with a full branching crown. A “Street Tree Grade” designation requires the highest grade of nursery shade or ornamental tree production which shall be supplied.

Trees with improperly pruned, broken, or damaged branches, trunk, or root structure shall be rejected. In all cases, whether supplied balled and burlapped or in a container, the root crown (top of root structure) of the tree shall be at the top of the finish soil level. Trees supplied and delivered in a nursery fabric bag will not be accepted.

Plants, which have been determined by the Engineer to have suffered damage as the result of girdling of the roots, stem, or a major branch; have deformities of the stem or major branches; have a lack of symmetry; have dead or defoliated tops or branches; or have any defect, injury, or condition which renders the plant unsuitable for its intended use, shall be rejected.

Plants that are grafted shall have roots of the same genus as the specified plant.

9-14.6(3) Handling and Shipping

Handling and shipping shall be done in a manner that is not detrimental to the plants.

The nursery shall furnish a notice of shipment in triplicate at the time of shipment of each truck load or other lot of plant material. The original copy shall be delivered to the Project Engineer, the duplicate to the consignee and the triplicate shall accompany the shipment to be furnished to the Inspector at the job site. The notice shall contain the following information:

1. Name of shipper.
2. Date of shipment.
3. Name of commodity. (Including all names as specified in the contract.)
4. Consignee and delivery point.
5. State contract number.
6. Point from which shipped.
7. Quantity contained.
8. Certificate of Grade. (Statement that material conforms to the specifications.)
9. Size. (Height, runner length, caliper, etc. as required.)
10. Statement of root pruning. (Date pruned and size of pruning.)
11. Signature of shipper by authorized representative.

To acclimate plant materials to Northwest conditions, all plant materials used on a project shall be grown continuously outdoors north of the 42nd Latitude (Oregon-California border) from not later than August 1 of the year prior to the time of planting.

All container grown plants shall be handled by the container.

All balled and burlapped plants shall be handled by the ball.

Plant material shall be packed for shipment in accordance with prevailing practice for the type of plant being shipped, and shall be protected at all times against drying, sun, wind, heat, freezing, and similar detrimental conditions both during shipment and during related handling. Where necessary, plant material shall be temporarily heeled in. When transported in closed vehicles, plants shall receive adequate ventilation to prevent sweating. When transported in open vehicles, plants shall be protected by tarpaulins or other suitable cover material. Antidesiccant material shall be applied before shipment.

9-14.6(4) Tagging

Plants delivered as a single unit of 25 or less of the same size, species, and variety, shall be clearly marked and tagged. Plants delivered in large quantities of more than 25 must be segregated as to variety, grade, and size; and one plant in each 25, or fraction thereof, of each variety, grade, and size shall be tagged.

9-14.6(5) Inspection

The Contracting Agency will make an inspection of plant material at the source when requested by the Engineer. However, such preliminary approval shall not be considered as final acceptance for payment. Final inspection and approval (or rejection) will only occur when the plant material has been delivered to the contract site. The Contractor shall notify the Engineer, not less than 48 hours in advance, of plant material delivery to the project.

9-14.6(6) Substitution of Plants

No substitution of plant material, species or variety, will be permitted unless evidence is submitted in writing to the Engineer that a specified plant cannot be obtained and has been unobtainable since the award of the contract. If substitution is permitted, it can be made only with written approval by the Engineer. The nearest variety, size, and grade, as approved by the Engineer, shall then be furnished.

Container or balled and burlapped plant material may be substituted for bare root plant material. Container grown plant material may be substituted for balled and burlapped plant materials. Container size shall be determined by the volume of the root ball that is specified. These substitutions shall be approved by the Engineer and be at no cost to the Contracting Agency.

9-14.6(7) Temporary Storage

Plants stored under temporary conditions shall be the responsibility of the Contractor.

Plants stored on the project shall be protected at all times from extreme weather conditions by insulating the roots, root balls, or containers with sawdust, soil, compost, bark or wood chips, or other approved material and shall be kept moist at all times prior to planting.

Cuttings to be stored for periods longer than one week shall be taken while the plants are dormant. Cuttings to be stored for later installation shall be bundled, laid horizontally, and completely buried under 6-inches of water, moist soil or placed in cold storage at a temperature of 34°F and 90% humidity. Cuttings that are not planted within 24 hours of cutting shall be soaked in water for 24 hours prior to planting. Cuttings taken when the temperature is higher than 50°F shall not be stored for later use.

Cuttings shall continually be shaded and protected from wind. Cuttings must be protected from drying at all times and shall be heeled into moist soil or placed in water if not installed within 8 hours of cutting.

9-14.6(8) Sod

The available grass mixtures on the current market shall be submitted to the Engineer for selection and approval.

The sod shall be field grown one calendar year or older, have a well developed root structure, and be free of all weeds, disease, and insect damage.

Prior to cutting, the sod shall be green, in an active and vigorous state of growth, and mowed to a height not exceeding 1-inch.

The sod shall be cut with a minimum of 1-inch of soil adhering.

9-14.7 Stakes, Guys, and Wrapping

Stakes shall be installed as shown in the Plans.

Commercial plant ties may be used in lieu of hose and wire guying upon approval of the Engineer. The minimum size of wire used for guying shall be 12 gage, soft drawn.

Hose for guying shall be nylon, rubber, or reinforced plastic and shall have an inside diameter of at least 1-inch.

Tree wrap shall be a crinkled waterproof paper weighing not less than 4.0-pounds per 100 square feet and shall be made up of two sheets cemented together with asphalt.

9-15 IRRIGATION SYSTEM

All materials and equipment incorporated in the system shall be new, undamaged, of standard quality, and shall be subject to testing as specified.

9-15.1 Pipe, Tubing, and Fittings

Pipe shall be copper, galvanized iron, PVC, or polyethylene, as specified in the Plans or in the Special Provisions.

Copper pipe or tubing shall be a minimum of Type L rating and shall meet the requirements of Section 9-30.6(3)A.

Threaded cast brass or bronze fittings shall meet the requirements of Section 9-30.6(6).

9-15.1(1) Galvanized Pipe and Fittings

Pipe shall be standard weight, hot-dip galvanized iron or steel pipe, threaded and coupled. Pipe shall meet the requirements of ASTM A 53.

All pipe fittings shall be standard threaded galvanized malleable iron fittings.

9-15.1(2) Polyvinyl Chloride Pipe and Fittings

PVC pipe and fittings shall be of PVC compound Type 1, Grade 1, conforming to ASTM D 1784 specifications. The pipe and fittings shall be approved and certified by the National Sanitation Foundation. Pipe and fittings shall be free from defects in materials, workmanship, and handling. The Engineer may require dimensional and quick burst tests of pipe and fittings after arrival at the job site. Acceptance of the materials shall be subject to passing the designated tests per ASTM Standards.

PVC solvent weld pipe shall be of PVC 1120 material and shall have 200-psi minimum pressure rating with SDR 21 walls which conform to ASTM D 2241. PVC pipe with walls heavier than SDR 21 shall be installed when noted in the Plans and specified in the Special Provisions. PVC threaded pipe shall be of PVC 1120 material and shall be schedule 80 which conforms to ASTM D 1785.

PVC pipe fittings shall conform to ASTM D 2466, Type I, Grades 1 or 2. Pipe may be belled on one end with the dimensions of the tapered bell conforming to ASTM D 2672.

Each length of PVC pipe is to be marked with an identifying extrusion “run” number and the manufacturer’s name or trade name plus the pipe size and schedule.

9-15.1(3) Polyethylene Pipe

Polyethylene pipe shall be Class 80, SDR 15, medium density polyethylene pipe, meet the requirements of ASTM D 2239, conform to U.S. Commercial Standard CS-255, and be National Sanitation Foundation (NSF) approved.

Thick walled polyethylene (poly) pipe shall be used in conjunction with fittings recommended by the manufacturer of the poly pipe to produce a flexible swing joint assembly between the lateral line and the irrigation head. The pipe shall be manufactured from high quality, low density virgin polyethylene material and have a minimum wall thickness of 0.10-inch and a minimum inside diameter of 0.49-inch. The pipe shall be capable of withstanding 80-psi operating water pressure at 110°F. The length of thick walled poly pipe at each flexible swing joint assembly shall be 18-inches minimum to 36-inches maximum.

9-15.2 Drip Tubing

Drip tubing shall be manufactured from specially formulated, chemical resistant, low to medium density virgin polyethylene or polybutylene selected for excellent weatherability and stress cracking resistance and designed specifically for use in drip irrigation systems. Drip tubing shall have a minimum wall thickness of 0.045-inch.

9-15.3 Automatic Controllers

Automatic controller pedestals or container cabinets shall be installed on a concrete base as shown in the Plans. The automatic controller clock shall be an electrically timed device for automatically opening and closing control valves for predetermined periods of time and mounted so that all normal adjustments will be conveniently located for use by the operator. The automatic controller clock shall be enclosed in a weatherproof, painted, metal housing fabricated from 16 gage sheet aluminum alloy 6061-T6, or from 16 gage sheet steel metal.

The automatic controller clock housing shall have hasp and lock or locking device. All locks or locking devices shall be master keyed and three sets of keys provided to the Engineer. The controller shall be compatible with and capable of operating the irrigation system as designed and constructed and shall include the following operating features:

1. Each controller station shall be adjustable for setting to remain open for any desired period of time, from five minutes or less to at least one hour.
2. Adjustments shall be provided whereby any number of days may be omitted and whereby any one or more positions on the controller can be skipped. When adjustments are made, they shall continue automatically within a 14-day cycle until the operator desires to make new adjustments.
3. Controls shall allow any position to be operated manually both on or off whenever desired.
4. Controls shall provide for resetting the start of the irrigation cycle at any time and advancing from one position to another.
5. Controllers shall contain an on-off switch and fuse assembly.

9-15.4 Spray Heads

Spray heads shall be of the type, pattern, and coverage shown in the Plans at rated operating pressure specified, discharging not more than the amount of gallons per minute listed.

Sprinkler heads shall be designed so that spray adjustments can be made by either an adjustment screw or interchangeable nozzles. Watering cores shall be easily removed without removing the housing from the pipe.

9-15.5 Valve Boxes and Protective Sleeves

All automatic control valves, flow control valves, and pressure reducing valves shall be provided with valve boxes. Valve boxes shall conform to the Plans and shall be extendible to obtain the depth required. All manual drain valves and manual control valves shall be equipped with a protective sleeve and cap as shown in the Plans.

9-15.6 Gate Valves

Gate valves when called for in the Plans shall be heavy duty bronze conforming to the requirements of ASTM B 62. Valves shall be of the same size as the pipes on which they are placed and shall have union or flange connections. Service rating (for nonshock cold water) shall be 150-psi. Valves shall be of the double disk, taper seat type, with rising stem, union bonnet and hand wheel or suitable cross wheel for standard key operation. Manufacturer's name, type of valve, and size shall be cast on the valve.

9-15.7 Control Valves

9-15.7(1) Manual Control Valves

Manual valves shall be bronze or brass, angle type with hex brass union. Service rating shall be not less than 150-psi nonshock cold water. Valves shall be designed for underground installation with suitable cross wheel for operation with a standard key. The Contractor shall furnish three suitable operating keys per contract. Valves shall have removable bonnet and stem assembly with adjustable packing gland and shall house long acme threaded stem to ensure full opening and closing. Valve discs shall be full floating with replaceable seat washers.

9-15.7(2) Automatic Control Valves

Automatic remote control valves shall be globe pattern with flanged or screwed connections as required. The valve shall be constructed so as to allow all internal parts to be removable from the top of the valve without disturbing the valve installation.

Valves shall be of a normally closed design and shall be electric solenoid operated, having maximum rating of 6.5 watts utilizing 24 volt AC power. Solenoids shall be directly attached to the valve bonnets or body with all control parts completely internal. Valves shall be of 150-psi brass or bronze, or iron body bronze mounted combination. The opening and closing speed of the valve shall be a minimum of five seconds for closure and a minimum of three seconds for opening with a constant rate of opening and closing. A manual control bleed cock shall be included on the valve to operate the valve without the requirement of electric current. A manual shutoff stem with cross handle for wrench operation is required for manual adjustment from fully closed to wide open. Once the manual adjustment is set, the valve shall operate automatically in the adjusted position. Water flow shall be completely stopped when the control valve is closed either manually or automatically. Automatic control valves and automatic controllers need not be from the same manufacturer.

9-15.7(3) Automatic Control Valves With Pressure Regulator

The automatic control valve with pressure regulator shall be similar to the automatic control valve and shall also reduce the inlet pressure to a constant lower pressure regardless of supply fluctuations. The regulator must be fully adjustable.

9-15.8 Quick Coupling Equipment

Quick coupler valves shall have a service rating not less than 125-psi for nonshock cold water. The body of the valves shall be of cast leaded semi-red brass alloy No. C84400 conforming to ASTM B 584. The base of the valve shall have standard female pipe threads. The design of the valve shall be such that it will open only upon inserting a coupler key and will close as the coupler is removed from the valve. Leakage of water between the coupler and valve body when in operation will not be accepted. The valve body receiving the coupler shall be designed with double worm slots to allow smooth

action in opening and closing of the valve with a minimum of effort. Slots shall be notched at the base to hold the coupler firmly in the open position. Couplers shall be of the same material as the valve body with stainless steel double guide lugs to fit the worm slots. Couplers shall be of one piece construction with steel reinforced side handles attached. All couplers shall have standard male pipe threads at the top. Couplers shall be furnished with all quick coupler valves unless otherwise specified.

9-15.9 Drain Valves

Drain valves shall be $^1/_2$ or $^3/_4$-inch in size and shall be of bronze or brass, manual angle globe type, with rising stem, hex brass union, removable bonnet and stem, and adjustable packing gland. Valves shall be designed for underground installation with suitable cross wheel for operation with a standard key, and shall have a service rating of not less than 150-psi nonshock cold water. The Contractor shall furnish three standard operating keys per contract.

On potable systems, drain valves shall be allowed only in the downstream side of approved cross connection control devices.

9-15.10 Hose Bibs

Hose bibs shall be constructed of bronze or brass, angle type threaded to accommodate a $^3/_4$-inch hose connection, and shall be key operated. Design shall be such as to prevent operation by wrench or pliers.

9-15.11 Cross Connection Control Devices

Atmospheric vacuum breaker assemblies (AVBAs), pressure vacuum breaker assemblies (PVBAs), double check valve assemblies (DCVAs), and reduced pressure backflow devices (RPBDs), shall be of a manufacturer and product model approved for use by the Washington State Department of Social and Health Services, Olympia, Washington.

9-15.12 Check Valves

Adjustable spring check valves shall be PVC and shall be pressure rated at 200-psi. Valves shall be adjustable from 5 to 15-pounds spring tension, but shall not cause pressure loss in excess of 5-psi for flows up to 30-gpm. Valves shall have angled seats, Buna-N seals and threaded connections, and shall be installed in 6-inch Schedule 40 PVC sleeves with removable caps or 6-inch round plastic valve boxes.

9-15.13 Pressure Regulating Valves

Pressure regulating valves shall have a minimum of 150 psi working pressure with an adjustable outlet range of 20 to 70-psi. The valves shall be factory set as shown in the Plans. Pressure regulating valves shall be rated for safe operation at 175-psi nonshock cold water.

9-15.14 Three-Way Valves

Three-way valves shall be tight closing, three port, ball or plug type, constructed to permit straight through and 90 degree flow only. The valve shall be of bronze or approved corrosion resistant body materials and shall have a minimum of 150-psi working pressure. The head of the valve, or handle when applicable, shall be permanently marked to indicate port position. Whenever handles are included as an integral part of the valve, the Contractor shall remove the handles and give them to the Engineer for ultimate distribution to the Maintenance Division.

9-15.15 Flow Control Valves

Valve body materials shall be plastic or metal. Internal parts shall be stainless steel. Valves shall be factory set to plan flows. Valves shall have no external adjustment and be tamper-proof when installed. One-quarter inch and smaller flow control valves shall have a minimum pressure absorption range of 2 to 32-psi. One and one half inch and larger flow control valves shall have a minimum pressure absorption range of 3 to 50-psi.

Flow shall be controlled to 5 percent of plan volumes.

9-15.16 Air Relief Valve

The air relief valve shall automatically relieve air and break a vacuum in the serviced pipe. Body materials shall be installed exactly at all high points.

9-15.17 Electrical Wire and Splices

Electrical wire used between the automatic controller and automatic control valves shall be copper AWG No. 14 minimum size, Type USE Chemically Cross Linked Polyethylene , Type UF, and shall be color coded or marked with number identification.

Low voltage splices shall be made with a kit containing a “T” shaped open cell centering device and a plastic bag of urethane and hardener which is mixed at the time of installation or heat shrinkable insulating tubing. Heat shrinking insulating tubing shall consist of a mastic lined heavy wall polyolefin cable sleeve. The resin used with the “T” shaped open cell centering device shall be a quick curing flexible compound with an approximate set-up time of 4 minutes at 72°F.

9-15.18 Detectable Marking Tape

Detectable marking tape shall consist of inert polyethylene plastic that is impervious to all known alkalis, acids, chemical reagents, and solvents likely to be encountered in the soil, with a metallic foil core to provide the most positive detection and pipeline locators.

The tape shall be color coded and shall be imprinted continuously over its entire length in permanent black ink. The message shall convey the type of line buried below and shall also have the word “Caution” prominently shown. Color coding of the tape shall be as follows:

Utility	Tape Color
Water	Blue
Sewer	Green
Electrical	Red
Gas/Oil	Yellow
Telephone/CATV	Orange

The width of the tape shall be as recommended by the manufacture for the depth of installation.

9-15.19 Wye Strainers

Wye strainers shall be bronze or brass with screwed end connections, 20 mesh Monel or stainless steel screen, and standard tapped bronze retainer cap and closure plug. Service rating shall be not less than 150-psi nonshock cold water.

9-16 FENCE AND GUARDRAIL

9-16.1 Chain Link Fence and Gates

9-16.1(1) General

All material used in the construction of chain link fence and gates shall be new. Iron or steel material shall be galvanized unless specified otherwise. Material upon which serious abrasions of galvanizing occur shall not be acceptable.

9-16.1(1)A Post Material for Chain Link Fence

Except as noted otherwise, post material shall conform to the requirements of AASHTO M 181, Type I (zinc-coated steel), Grade 1 or 2, and shall be understood to include all round and roll-formed material (brace rails, top rails, line posts, brace posts, end posts, corner posts and pull posts).

Grade 1 post material shall conform to the weight per linear foot, minimum wall thickness and detail requirements of Standard Plan L-2. Grade 1 post material that exceeds the maximum wall thickness requirement of Standard Plan L-2 may be accepted, provided it does not interfere with the proper construction of the fence.

Grade 2 post material shall meet the organic exterior coatings requirements of AASHTO M 181 (Section 33) and the additional requirement that the interior coated surface shall be capable of resisting 300 hours of exposure to salt fog with a maximum of 5% red rust when tested in accordance with ASTM B 117.

- Round Post Material

  Round post material shall be Grade 1 or 2.
- Roll Form Material

  Roll-formed post material shall be Grade 1. Roll-formed end, corner, and pull posts shall have integral fastening loops to connect to the fabric for the full length of each post. Top rails and brace rails shall be open rectangular sections with internal flanges as shown in Standard Plan L-2.

9-16.1(1)B Chain Link Fence Fabric

Chain link fabric shall consist of 11 gage wire for Types 3, 4, and 6 fence, and 9 gage wire for Type 1 fence. The fabric shall be zinc-coated steel wire conforming to AASHTO M 181, Class C.

The wire shall be woven into approximately 2-inch diamond mesh. The width and top and bottom finish of the fabric shall be as specified in AASHTO M 181.

9-16.1(1)C Tension Wire

Tension wire shall meet the requirements of AASHTO M 181. Tension wire galvanizing shall be Class 1.

9-16.1(1)D Fittings and Hardware

Except where indicated, fittings shall be malleable cast iron or pressed steel and shall conform to the requirements of ASTM F626 or AASHTO M232, whichever is applicable. Fittings for any particular fence shall be those furnished by the manufacturer of the fence.

Tension truss rods shall be $^{3}/_{8}$-inch round galvanized rods with drop forged turnbuckles or other approved type of adjustment. Couplings for tubular sections shall be outside sleeve type and shall be at least 6-inches long.

Eye bolts for attaching tension wire shall be $^{3}/_{8}$-inch diameter and of sufficient length to fasten to the type of post being used.

Tension bars shall be $^{3}/_{16}$-inch by $^{3}/_{4}$-inch nominal and cross sectional area shall be 0.141 in^2 +/- 5%.

Hog rings shall be 12 gage galvanized steel wire. Tie wire shall be 9 gage galvanized steel wire or 9 gage aluminum wire meeting the requirements of ASTM F626.

9-16.1(1)E Chain Link Gates

Gate frames shall be constructed of not less that $1^{1}/_{2}$-inch (I.D.) hot-dipped galvanized pipe conforming to AASHTO M 181 Type I, Grade 1 or 2 as specified in Section 9-16.1(1)A. The corners of the gate frame shall be fastened together and reinforced with a malleable iron or pressed steel fitting designed for the purpose, or they may be welded. Welding shall conform to the requirements of Section 6-03.3(25). All welds shall be ground smooth and painted with an A-9-73 or A-11-99 primer meeting the requirements of Section 9-08.2. The paint shall be applied in one or more coats to provide a minimum dry film thickness of 3.5 mils.

Chain link fence fabric for filling the gate frame shall meet the requirements of Section 9-16.1(1)B for the fence type being furnished.

Cross trussing shall be $^{5}/_{16}$-inch steel adjustable rods galvanized in accordance with Section 9-16.1(1)D.

Each gate shall be furnished complete with necessary hinges, latch, and drop bar locking device designed for the type of gate posts and gate used on the project. Gates shall have positive type latching devices with provisions for padlocking. Hinges, latches, and locking devices shall be galvanized in accordance with Section 9-16.1(1)D.

Gate frames constructed of steel sections, other than pipe, that are fabricated in such a manner as to form a gate of equal or better rigidity may be used provided they are approved by the Engineer.

9-16.1(1)F Concrete

All concrete for chain link fence shall be as specified in Section 6-02.3(2)B.

9-16.1(2) Approval

Approval of materials for chain link fence shall be by evaluation of independent test results from a certified testing laboratory or by QPL. Independent test results for evaluation shall be submitted to the State Materials Engineer in Tumwater WA.

9-16.2 Wire Fence and Gates

9-16.2(1) General

All materials used in the construction of the wire fence shall be new. All iron or steel material shall be galvanized. Material upon which serious abrasions of galvanizing occur will not be acceptable.

9-16.2(1)A Steel Post Material

- **Round Post Material**

  Round post material shall conform to AASHTO M 181, Type I, Grade 1.

- **Angle Post Material** (Channel, T, U, Y, or Other Approved Style)

  All angle post material shall be hot-dipped galvanized in accordance with the requirements of AASHTO M 111 grade 75. Galvanizing shall be 1.7 oz/ft^2 of surface area. Angle post used for end, corner, gate and pull post and brace shall have a minimum weight of 3.1 lb/ft.

Posts shall be not less than 7-feet in length. A tolerance of -5% on the weight of individual posts, braces or anchor plates will be permitted. One type of line post shall be used throughout the project. Line posts shall be studded, slotted, or properly adapted for attaching either wire or mesh in a manner that will not damage the galvanizing of posts, wire or mesh during the fastening. Line posts shall have a minimum weight of 1.33 lbs/ft and shall be provided with a tapered galvanized steel anchor plate. The anchor plate shall be securely attached and have a surface area of 20 +/-2 in^2, a minimum weight of 0.67 pounds and 1.7 oz/ft^2 galvanizing.

9-16.2(1)B Wood Fence Posts and Braces

Douglas fir, Western red cedar, hemlock, or larch shall be used in the construction of wood fence posts and braces. The material shall be of good quality and approved by the Engineer before use. Peeler cores shall not be used for round posts. Wood fencing materials shall have sufficient sapwood in the outer periphery to obtain the specified penetration of preservative. Western red cedar will not require preservative treatment. Fencing materials shall be cut to the correct length before pressure treatment.

Line posts shall be 3-inch minimum diameter round posts or nominal 3-inch by 3-inch square sawed posts. If the posts are to be pointed for driving, they shall be pointed before treatment. Line posts shall be at least 7-feet in length.

Pull posts and brace posts shall be 6-inch diameter round posts or nominal 6-inch by 6-inch material not less than 7-feet in length.

End, gate, and corner posts, and posts at an intersecting fence shall be 6-inch diameter round posts or nominal 6-inch by 6-inch material not less than 7-feet 10-inches in length.

All sawed posts and timbers shall meet the requirements in the table under Section 9-09.2.

The preservatives used to pressure treat wood fencing materials shall meet the requirements of Section 9-09.3.

The retention and penetration of the preservative shall be as follows:

Minimum Retention in Pounds Per Cubic Foot		
Preservative	**Sawed Posts**	**Round Posts**
Creosote	10.00	8.00
Pentachlorophenol	0.50	0.40
ACA	0.40	0.40
ACZA	0.40	0.40
CCA	0.40	0.40

Minimum Penetration

for material 5” or less - 0.40-inches penetration and 90% of sapwood

for material 5” or greater - 0.50-inches penetration and 90% of sapwood

9-16.2(1)C Brace Wire

Brace wire shall be 9 gage wire galvanized to meet the requirements of AASHTO M 279, Type Z, Class 1.

9-16.2(1)D Staples and Wire Clamps

The staples used to attach the wire fencing to wood posts shall be 9 gage wire, $1^1/_2$-inches long, galvanized to meet the requirements of AASHTO M 279, Type Z, Class 1.

The wire clamps used to attach the wire fencing to steel posts shall be 11 gage wire, galvanized to meet the requirements of AASHTO M 279, Type Z, Class 1.

9-16.2(1)E Barbed Wire

Barbed wire shall conform to the requirements of AASHTO M 280, Type Z and shall consist of two strands of $12^1/_2$ gage wire, twisted with four point 14 gage barbs with barbs spaced 5-inches apart (Design 12-4-5-14R). Galvanizing shall be Class 3.

9-16.2(1)F Wire Mesh

Wire mesh shall conform to the requirements of AASHTO M 279, Type Z and shall consist of eight horizontal wires with vertical stays spaced 6-inches apart. The top and bottom wires shall be 10 gage, and the intermediate wires and vertical stays shall be $12^1/_2$ gage. The mesh shall have a total width of 32-inches (Design 832-6-$12^1/_2$). Galvanizing shall be Class 3.

The zinc coated wire as represented by the test specimens shall be capable of being wrapped in a close helix at a rate not exceeding 15 turns/minute around a cylindrical steel mandrel having a diameter the same as the specimen being tested, without cracking or flaking the zinc coating to such an extent that any zinc can be removed by rubbing with the bare fingers.

9-16.2(1)G Vertical Cinch Stays

Vertical cinch stays shall be 10 gage galvanized wire meeting the requirements of AASHTO M 279, Type Z, Class 1.

9-16.2(1)H Miscellaneous Hardware

Bolts, nuts, hinges, latches and other miscellaneous hardware shall be galvanized in accordance with AASHTO M 232.

9-16.2(1)I Wire Gates

Gate frames shall be constructed of galvanized pipe with a nominal diameter of not less than 1-inch. The pipe shall conform to the requirements of AASHTO M 181 Type I, Grade 1. Wire gates shall be not less than 48-inches in height and shall be designed to fit openings of the width called for in the Plans or as indicated by the bid items. Each gate shall be provided with two upright braces of the same material as the frame, spaced at $^1/_3$ points in the gate. All gates shall be provided with adjustable $^5/_{16}$-inch diameter galvanized diagonal truss rods from corner to corner. Galvanizing shall be in accordance with Section 9-16.2(1)H.

The gate frame shall be provided with wire mesh conforming to the requirements specified in Section 9-16.2(1)F, except that it shall consist of 10 horizontal wires and have a total width of 47-inches.

Each gate shall be furnished complete with necessary galvanized hinges and latch designed for use with the type of gate posts used on the project. The hinges shall be so designed as to be securely attached to the gate post and to enable the gate to be swing back against the fence. Double gates shall be hinged in the same manner as single gates and shall be provided with an approved galvanized drop bar locking device. Galvanizing for hinges, latches, and locking devices shall be in accordance with Section 9-16.2(1)H.

9-16.2(1)J Concrete

All concrete for wire fence shall be as specified in Section 6-02.3(2)B.

9-16.2(2) Approval

Approval of materials for wire fence shall be by evaluation of independent test results from a certified testing laboratory or by QPL. Independent test results for evaluation shall be submitted to the State Materials Engineer in Tumwater WA.

9-16.3 Beam Guardrail

9-16.3(1) Rail Element

The W-beam or thrie beams rail elements, backup plates, reducer sections, and end sections shall conform to "A Guide to Standardized Highway Barrier Hardware" published by AASHTO, AGC, and ARTBA. All rail elements shall be formed from 12 gage steel except for thrie beam reducer sections, thrie beams used for bridge rail retrofits, and Design F end sections, which shall be formed from 10 gage steel.

The rail splices shall have a minimum total ultimate strength of 80,000 pounds at each joint.

The 6-inch channel rails and splice plates shall conform to ASTM A 36, except that the channel rails may conform to ASTM A 992. All fabrication shall be complete before galvanizing.

The holes in the plate shall be slotted to facilitate erection and to permit expansion and contraction. The edges of the rail shall be rolled or rounded so they will present no sharp edges. Where the rail is on a curve, the plates at the splice shall make contact throughout the area of splice. When the radius of curvature is less than 150-feet, the rail shall be shaped in the shop.

9-16.3(2) Posts and Blocks

Posts and blocks may be of creosote treated timber, pentachlorophenol treated timber, waterborne chromated copper arsenate (CCA), ammoniacal copper arsenate (ACA), or ammoniacal copper zinc arsenate (ACZA), treated timber or galvanized steel; except only treated timber posts and blocks may be used for weathering steel beam guardrail.Blocks made from alternate materials that meet the NCHRP Report 350 criteria may be used in accordance with the manufacturer's recommendations. Except for terminal or anchor assemblies, all posts for any one project shall be of the same type (wood or steel). Posts and blocks shall be of the size and length shown in the Plans and meet the requirements of these Specifications. Posts and blocks may be S4S or rough sawn.

Timber posts and blocks shall conform to the grade specified in Section 9-09.2, except pine lumber No. 1 grade may be used for the blocks. Timber posts and blocks shall be fabricated as specified in the Plans before being treated. Timber posts and blocks shall be treated by the empty cell process to provide a minimum retention, depending on the treatment used, according to the following:

Creosote oil	12.0 lbs. pcf.
Pentachlorophenol	0.60 lbs. pcf.
ACA	0.50 lbs. pcf.
ACZA	0.50 lbs. pcf.
CCA	0.50 lbs.pcf.

Treatment shall be in accordance with Section 9-09.3.

Steel posts, blocks, and base plates, where used, shall conform to either ASTM A 36 or ASTM A 992, and shall be galvanized in accordance with AASHTO M 111. Welding shall conform to Section 6-03.3(25). All fabrication shall be completed prior to galvanizing.

9-16.3(3) Galvanizing

Beam rail elements and terminal sections shall be galvanized in accordance with AASHTO M-180, Class A, Type 2, except that the rail shall be galvanized after fabrication, with fabrication to include forming, cutting, shearing, punching, drilling, bending, welding, and riveting. In addition, the minimum average mass of zinc coating shall be 2 ounces per square foot of surface (not sheet), the average to be determined on the basis of three individual tests, no one of which may be less than 1.8 ounces per square foot of surface (not sheet). The aluminum content of the zinc bath during actual galvanizing operations shall not exceed 0.01 percent. Channel rails, splice plates, WF steel posts, and base plates shall be galvanized in accordance with ASTM A 123. Anchor cables shall be galvanized in accordance with Federal Specification RR-W-410, Table II, galvanized at finished size. Bolts, nuts, washers, plates, rods, and other hardware shall be galvanized in accordance with ASTM A 153.

9-16.3(4) Hardware

Bolts, unless otherwise specified, shall comply with ASTM A 307 Grade A specifications. High strength bolts shall conform to the requirements of AASHTO M 164. Nuts, unless otherwise specified, shall comply with ASTM A 563 Grade A specifications. Washers, unless otherwise specified, shall meet ASTM F 844 specifications. The Contractor shall submit a manufacturer's certificate of compliance for high strength bolts, nuts, and washers prior to installing any of the hardware. A307 Bolts will be accepted by field verification and documentation that bolt heads are stamped 307A.

9-16.3(5) Anchors

Welding shall conform to Section 6-03.3(25).

All welding shall be equal in strength to the parent metal.

All fabrication shall be complete and ready for assembly before galvanizing. No punching, drilling, cutting, or welding will be permitted after galvanizing unless authorized by the Engineer.

Foundation tubes shall be fabricated from steel conforming to the requirements of ASTM A 500, Grade B or ASTM A 501.

The anchor plate assembly shall develop a minimum tensile strength of 40,000 pounds.

The anchor plate, W8 x 18, and metal plates shall be fabricated of steel conforming to the specifications of ASTM A 36, except that the W8 x 18 may conform to ASTM A 992.

Anchor cable shall be ¾-inch preformed, 6 × 19 wire strand core or independent wire rope core (IWRC), galvanized, right regular lay manufactured of improved plow steel with a minimum breaking strength of 42,800 pounds. Two certified copies of mill test reports of the cable used shall be furnished to the Engineer.

Swaged cable fittings shall develop 100 percent of the specified breaking strength of the cable. One swaged fitting attached to 3-feet of cable shall be furnished to the Engineer for testing.

The swaged fitting and stud assembly shall be of steel conforming to the requirements of American Iron and Steel Institute C-1035 and shall be annealed and galvanized suitable for cold swaging.

All metal components of the anchor and cable assembly and not less than the top 14-inches of the W8 × 18 for the Type 2 anchor shall be hot-dip galvanized in accordance with Section 9-16.3(3).

Cement concrete shall conform to the requirements of Section 6-02.3(2)B.

Cement grout shall consist of one part Portland cement and two parts sand.

9-16.3(6) Inspection and Acceptance

The Contractor shall give notice to the Engineer before the rail elements are fabricated in order that inspections may be provided. The Contractor shall arrange for all facilities necessary for the inspection of material and workmanship at the point of fabrication of the rail element, and inspectors shall be allowed free access to necessary parts of the premises.

The Inspector shall have the authority to reject materials or workmanship which do not fulfill the requirements of these Specifications. In cases of dispute, the Contractor may appeal to the Engineer, whose decision will be final.

The Inspector may accept a mill test report certifying that the steel used in fabricating the rail element meets the requirements of the specifications. The Contracting Agency reserves the right, however, to require the Contractor to furnish samples of the steel proposed for use and to determine to its satisfaction that the steel meets the specification requirements. Steel rail elements, fittings, end section hardware, and bolts may be accepted by the Engineer based on the Manufacturer's Certification of Compliance.

9-16.4 Wire Mesh Slope Protection

9-16.4(1) General

All metal material used in the construction of wire mesh slope protection shall be new and galvanized. Imperfectly galvanized material or material upon which serious abrasion of galvanizing occurs will not be acceptable.

9-16.4(2) Wire Mesh

The galvanized wire mesh shall consist of No. 9 gage (0.148-inch diameter) commercial quality zinc coated steel wire, 3½-inches × 5½-inches diamond mesh chain link conforming to the requirements of AASHTO M 181. Galvanizing shall conform to the requirements of ASTM A 392 except the weight of zinc coating shall be 0.80 ounce per square foot minimum, of uncoated wire surface. Galvanizing shall be done before weaving.

The wire mesh fabric shall have knuckled selvages.

Alternate wire mesh for slope protection shall be double twisted mesh. The mesh shall be of nonraveling construction and consist of a uniform double twisted hexagonal mesh of hot-dip galvanized steel wire having a diameter of 0.120-inch after galvanization. The wire shall be galvanized prior to weaving into the mesh and shall conform to ASTM A 641, Class 3, Finish 5, Soft temper. The minimum tensile strength shall be 60,000 psi when tested in accordance with ASTM A 370. Openings shall be hexagonal in shape and uniform in size measuring not more than 3¼-inches by 4½-inches, approximately 9 square inches. Lacing wire shall be the same specifications as the wire used in the wire mesh except that its diameter shall be 0.0866-inch after galvanization.

Edges shall be mechanically selvaged in such a manner as to prevent unraveling, and shall develop the full strength of the mesh. The wire used for the selvage shall have a nominal diameter of 0.1535-inch.

9-16.4(3) Wire Rope

Wire rope shall be ⅝-inch diameter zinc coated steel structural wire rope conforming to the requirements of ASTM A 603, Class A.

9-16.4(4) Hardware

All rings shall be drop-forged steel, heat treated after forging. Lightweight wire rope thimbles weighing approximately 13.8 pounds per hundred shall be used with the ½-inch diameter wire rope. Wire rope clips may be drop-forged steel or cast steel for use with ½-inch wire rope. All rings, thimbles, wire rope clips, and U-bolts shall be galvanized in accordance with AASHTO M 232, Class C, except castings shall be Class A, and forgings shall be Class B.

9-16.4(5) Hog Rings and Tie Wire

Hog ring fasteners and tie wire shall be manufactured of 9 gauge steel wire meeting Federal specification QQ-W-461 (AISI numbers 1010 and 1015) finish 5; medium hardness and tensile strength; Class 3 coating.

9-16.4(6) Grout

When required, grout for anchors shall consist of one part Portland cement and three parts of clean sand. The Portland cement shall conform to the requirements of Section 9-01.2(1).

9-16.4(7) Anchor Rods

Anchor rods shall be of good quality steel. The eye may be drop forged or formed with a full penetration weld and shall develop 100 percent of the rod strength. The anchor rod shall be galvanized in accordance with ASTM A 153.

9-16.5 Vacant

9-16.6 Glare Screen

9-16.6(1) General

All material used in the construction of the fence shall be new. Iron or steel material shall be galvanized or aluminum coated as specified. Imperfectly galvanized or aluminum coated material, or material upon which serious abrasions of galvanizing or aluminum coating occur, will not be acceptable.

9-16.6(2) Glare Screen Fabric

Glare screen fabric shall consist of diamond woven wire mesh. The fabric wire may be 0.148-inch diameter aluminum alloy complying with the Aluminum Association requirements for alloy 6061T94, or it may be 0.148-inch diameter (9 gage) iron or steel wire which shall meet all of the requirements of ASTM A 392 galvanized or A 491 for aluminum coated, except that galvanizing of Type 2 glare screen fabric shall be not less than 0.8 ounce per square foot and shall be done before weaving. Aluminum coating shall be Class II.

Type 1 glare screen mesh size shall be approximately a 1-inch diamond. Type 2 glare screen mesh size shall be a maximum of 3½-inch vertical and 5½-inch horizontal. The design shall permit the slats to be installed in a vertical position as shown in the Plans without distortion of the slats.

9-16.6(3) Posts

Line posts for Type 1 glare screen shall be 1.5-inches by 1.875-inches hot-dip galvanized steel H column with a minimum weight of 2.8 pounds per linear foot. Line posts for Type 2 glare screen shall be 1.95-inches by 2.25-inches hot-dip galvanized steel H column with a minimum weight of 4.0 pounds per linear foot, or 2-inch inside diameter hot-dip galvanized steel pipe with a nominal weight of 3.65 pounds per linear foot provided only one type shall be used on any one project.

End, corner, brace, and pull posts shall be 2-inch inside diameter hot-dip galvanized steel pipe with nominal weight of 3.65 pounds per linear foot. Intermediate pull posts (braced line posts) shall be H column as specified for line posts. Brace post sleeves shall be 2½-inch inside diameter hot-dip galvanized steel pipe with nominal weight of 5.79 pounds per linear foot.

The base material for the manufacture of steel pipes used for posts shall conform to the requirements of ASTM A 53, except the weight tolerance on tubular posts shall be applied as provided below. The base material for the manufacture of steel H columns shall meet the requirements of ASTM A 675.

Posts provided for glare screen will have an acceptance tolerance on the weight per linear foot, as specified, equal to plus or minus 5 percent for tubular and H-section posts. This tolerance will apply to each individual post.

All posts, braces, and top rails shall be hot-dip galvanized. They shall have a minimum average of 1.8 ounces zinc coating per square foot of surface area with no individual test being below 1.6 ounces zinc coating per square foot of surface area. In the case of members made from pipe, this area is defined as the total area inside and outside. A sample for computing the average of mass of coating is defined as a 12-inch piece cut from each end of the galvanized member.

9-16.6(4) Tension Wire

Top and bottom tension wire shall be 7 gage coil spring steel wire of good commercial quality and shall have a zinc coating averaging 0.8 ounces per square foot of surface area.

9-16.6(5) Cable

The tension cable shall be ¼-inch diameter aluminum coated or hot-dip galvanized, 7 wire strand steel cable conforming to the requirements of ASTM A 474 for aluminum coated or A 475 for galvanized, High-Strength Grade. Galvanizing shall be Class A.

9-16.6(6) Cable and Tension Wire Attachments

All tension wire and cable attachments shall be hot-dip galvanized steel conforming to the requirements of AASHTO M 232 unless otherwise specified. Eye bolts shall have either a shoulder or a back-up nut on the eye end and be provided with an eye nut where needed or standard hex nut and lock washer and be ⅝-inch diameter for tension cable and ⅜-inch diameter for tension wire and of sufficient length to fasten to the type of posts used. Where the eye bolt is to be installed through a pipe section, two lead washers and one steel washer shall also be provided. Turnbuckles shall be of the shackle end type, ½-inch diameter, with standard take-up of 6-inches and provided with ⅜-inch diameter pins. Thimbles shall be light weight wire rope thimbles for use with ¼-inch diameter cable. Wire rope clips shall have a U-bolt diameter of 5⁄16-inch for use with ¼-inch diameter cable. Anchor shackles shall be ⅜-inch diameter with a minimum distance between eyes of 1 1⁄16-inches and a pin diameter of 7⁄16-inch. Seizing shall be 0.032-inch diameter galvanized annealed iron wire.

9-16.6(7) Slats

9-16.6(7)A Wood Slats

Wood slats shall be ⅜-inch by 2⅜-inch by the height designation of the fence. Material shall be finished and treated cedar or redwood and shall be free from loose knots, cracks, and other imperfections. A dimensional tolerance of plus or minus 1⁄16-inch in width or thickness is allowed provided that the maximum space between slats does not exceed ¾-inch.

9-16.6(7)B Plastic Slats

Plastic slats shall be ⅜-inch by 2⅜-inch by the height designation of the fence. They shall be manufactured from tubular polyethylene color pigmented material consisting of high density virgin polyethylene and color pigments, designed to retard ultraviolet penetration. The material shall have a minimum wall thickness of 0.0030-inch plus or minus 0.0003-inch and shall remain flexible without distortion and without becoming brittle through a temperature range of -70ºF to + 250ºF. Tensile strength shall be at least 3,600 psi and the melt index shall not exceed 0.25.

Plastic slats shall be retained in place by means of U-shaped retainer members at the bottom and top of the fence. Retainer members shall be of the same material as the slats.

The color for plastic slats will be approved by the Engineer from samples submitted by the Contractor or supplier.

9-16.6(8) Fittings

Fittings shall be malleable cast iron or pressed steel and galvanized in accordance with the requirements of AASHTO M 232.

Fittings for any particular fence shall be those furnished by the manufacturer of the fence.

9-16.6(9) Fabric Bands and Stretcher Bars

Fabric bands shall be ⅛-inch by 1-inch nominal and stretcher bars 3⁄16-inch by ¾-inch nominal. Nominal shall be construed to be the area of the cross section of the shape obtained by multiplying the specified width by thickness. A variation of minus 5 percent from this theoretical area shall be construed as “nominal” size. Both shall be hot-dip galvanized to meet the requirements of ASTM F 626.

9-16.6(10) Tie Wire

Tie wire shall be 9 gage aluminum wire complying with the ASTM B 211 for alloy 1100 H14 or 9 gage galvanized wire meeting the requirements of AASHTO M 279. Galvanizing shall be Class 1.

9-16.7 Vacant

9-16.8 Weathering Steel Beam Guardrail

9-16.8(1) Rail and Hardware

Steel for rail elements and terminal sections shall conform to ASTM A 606 or ASTM A 607. Bolts, nuts, and washers for installation of weathering steel shall meet the requirements of Section 9-16.3(4), and be galvanized in accordance with Section 9-16.3(3). If required, 6-inch channels and fittings shall conform to ASTM A 242. In addition, all steel for the guardrail components shall conform to one of the following chemical compositions, percent (ladle):

Composition

	C	Mn	P	S	Si	Cu	Cr	Ni	Zr
No. 1	0.12 Max.	0.20 to 0.50	0.07 to 0.15	0.05 Max.	0.25 to 0.75	0.25 to 0.55	0.30 to 1.25	0.65 Max.	
No. 2	0.12 Max.	0.50 to 1.00	0.12 Max.	0.05 Max.	0.20 to 0.90	0.50 Max.	0.40 to 1.00	1.00 Max.	0.10 Max.

Blast cleaning or pickling to remove mill scale will not be required. All fabricated steel parts shall be handled with care to avoid gouges, scratches, and dents. The steel shall be kept clean of all foreign material, such as paint, grease, oil, chalk marks, crayon marks, concrete spatter, or other deleterious substances. Natural oxidation of the steel will not be considered foreign material. Storage in transit, in open cars and trucks, for an extended period will not be permitted. Steel parts stored outside in yards or at job sites shall be positioned to allow free drainage and air circulation.

9-16.8(2) Anchors

Guardrail anchors may either be furnished as provided in Section 9-16.3(5) or they may be nongalvanized and fabricated from steel conforming to ASTM A 242 with the exception that all Type 1 anchors shall have galvanized cable and fittings as specified in Section 9-16.3(5).

9-17 FLEXIBLE GUIDE POSTS

9-17.1 General

Flexible guide posts shall be made of a flexible, nonwarping, nonmetallic, durable plastic material; shall be resistant to damage due to impact, ultraviolet light, ozone, hydrocarbons, and other effects of atmospheric weathering; shall resist stiffening with age; and shall exhibit good workmanship and be free of burns, discoloration, contamination and other objectionable marks or defects that affect appearance or serviceability. The portion of ground mounted guide post installed below ground may be the same material as the portion above ground or other durable material suitable for firmly anchoring the post in the ground. When iron or steel are used for the in ground portion, galvanize in accordance with AASHTO M 111. The top of tubular posts shall be closed to prevent moisture or debris from entering. Surface mounted guide posts shall be mounted on a base made of a rigid high impact resistant material and be resistant to ultraviolet light, ozone, and hydrocarbons. The post shall mount directly into or onto the base in a tamper proof manner and shall allow for easy replacement. Guardrail mounted guide posts shall be the same as ground mounted guide posts except the length shall be adjusted to meet the mounting height requirements in the Standard Plans. Appropriate holes shall be provided for fastening the guide post to the guard rail post.

The material composition of flexible guide posts subsequently furnished shall not vary from that of the samples upon which the State Materials Laboratory pre-approval is based. If analysis by the Materials Laboratory determines there is a change in material composition, such change shall constitute grounds for rejection and/or removal from the Qualified Products List.

The post system shall be designed for permanent installation to resist overturning, twisting, and displacement from wind and impact forces.

Each flexible guide post shall be permanently identified with the manufacturer's name, and the month and year of fabrication. Ground mounted guide posts shall have a permanent a mark indicating the recommended burial depth. The letters shall be solvent resistant, a minimum of ¼-inch in height, and permanently affixed to the post.

Unless otherwise specified, the color of the guide post shall be white or brown as indicated in the Plans.

The reflective panel on a flat or elliptical guide post shall have a minimum width of 3-inches facing traffic. The reflective sheeting shall have a minimum area of 24 square inches (3-inches by 8-inches). The reflective panel on a round guide post shall have an 8-inch minimum band of reflective sheeting visible for 360 degrees.

9-17.1(1) Dimensions

1. Flat Type – The post has a minimum width of 3-inches of continuous flat surface with no curvature for the entire length of the post. This will allow for ridges on the outer edges and back of post intended for structural support.
2. Tubular Type – The post is tubular or round/circular in shape. This allows for a tubular post with a minimum diameter of 3-inches or a tubular post with a minimum diameter of 2-inches with a flat or flattened oval surface at least 3-inches wide and 12-inches long measured from the top for mounting reflective sheeting.

3. Non-flat and Non-tubular Type – This includes all post that do not fit into the two types indicated above. This would include convex, w-shape, oval, and other post designs. The post shall be wide enough to accept a 3-inch wide reflective sheeting. Any curvature or rounding shall not significantly reduce the brightness value of the reflective sheeting.
4. Surface Mount Guide Post Base – The base for surface mount guide posts shall be approximately 8-inches in diameter with a maximum height of 2-inches.
5. Guide posts shall be of such length to provide the required mounting height above the pavement surface in accordance with the Standard Plans.

9-17.1(2) Reflective Sheeting

Reflective sheeting for guide posts shall be Type III, IV, V, or VII conforming to Section 9-28.12. The reflective panel on a flat or elliptical guidepost shall have a minimum width of 3-inches facing traffic. The reflective sheeting shall have a minimum area of 24 square inches (3-inches by 8-inches). The reflective panel on a round guidepost shall have an 8-inch minimum band of reflective sheeting visible for 360 degrees. Mount the reflective sheeting on the guide post as detailed in the Standard Plans. Sheeting shall remain in place during the life of the post.

9-17.2 Ultraviolet Resistance Test Procedure (Laboratory Test)

Two posts will be tested initially for tensile strength and elongation according to ASTM D-638 and again after 1,000 hours QUV weatherometer exposure (ASTM G53).

Six bow tie specimens shall be prepared from the delineator post samples submitted for the purpose of ultraviolet (UV) exposure. The specimens shall be cycled at 1,000 hours in a weatherometer in accordance with ASTM G 53 (3 hr. 60C UV, 3 hr. 50C CON). Three of each type shall be used for control purposes. The remaining three shall be subjected to 1000 hours of UV exposure in the QUV weatherometer. Specimen dimensions conform to those outlined below.

The laboratory test data shall summarize the tensile strength of each, and the average tensile strength for both control and weathered samples. The data shall also summarize the elongation of each, and the average elongation for both control and weathered samples. The average values shall be used to show the percent change in tensile and elongation.

9-17.2 (1) Acceptance

The specimens shall show no signs of delamination, distress, or discoloration. Physical properties of tensile strength and rigidity shall be maintained within 80 percent of the unconditioned values.

9-17.3 Field Impact Test Procedure

Sample size of eight units will be tested the following way:

Flexible Ground Mounted Posts

Eight flexible ground mounted posts installed by the manufacturer (four installed manually and four installed mechanically). The delineators will be hit ten times (four posts for glancing bumper hits and four posts for wheel hits). A standard sedan with a bumper height of approximately 18” while traveling at a speed of 55 ± 2 mph will be used for impact testing. Five of the impacts will be at an ambient temperature of 32 ± 5°F and the remaining five impacts at an ambient temperature of 85 ± 5°F. The test vehicle shall impact four of the posts at an angle perpendicular to the front of the post

and shall impact the remaining posts at an angle of 25 degrees clockwise from the angle perpendicular to the front of the posts. The same test samples will be used for the ten hits. Two flexible posts will be used for weatherometer testing. A glancing hit is defined as one on the bumper near the vehicle headlight. The delineators shall be installed a minimum of eight hours prior to being hit.

Flexible Surface Mounted Posts

Eight flexible surface mounted posts installed by the manufacturer will be hit ten times (four posts for glancing bumper hits and four posts for wheel hits). A standard sedan with a bumper height of approximately 18" while traveling at a speed of 55 ± 2 mph will be used for impact testing. Five of the impacts will be at an ambient temperature of 32 ± 5°F and the remaining five impacts at an ambient temperature of 85 ± 5°F. The test vehicle shall impact four of the posts at an angle perpendicular to the front of the post and shall impact the remaining posts at an angle of 25 degrees clockwise from the angle perpendicular to the front of the posts. The same test samples will be used for the ten hits. Two flexible posts will be used for weatherometer testing. A glancing hit is defined as one on the bumper near the vehicle headlight. The delineators shall be installed a minimum of eight hours prior to being hit.

9-17.3 (1) Test Observations

Inspect each post after each impact and document the following:

1. Any splits, cracks, breaks or other forms of deformation or distress;
2. The percent list to vertical two minutes after each impact;
3. The approximate percentage of the reflective area that is damaged after each impact to an extent it no longer performs as intended;
4. Any problems or comments associated with the installation and removal of the posts and bases. The testing agent will document any special equipment or techniques required for installing or removing the posts and bases.
5. Any problems or comments associated with the performance of each ground mounted flexible delineator post that would be of interest to the states;
6. Type of soil and impact surface.

9-17.3 (2) Acceptance

A failure is defined as any of the following:

1. A minimum of 50 percent of the reflective sheeting shall be retained undamaged. An area of damage greater than 50 percent is considered a failure.
2. If the guide post leans more than 10 degrees from vertical it is considered a failure.
3. Any cracking, other than surface cracking evident on only one face of the post, is considered a failure.
4. Pullout in excess of 3-inches is considered a failure.

At least six of the guide posts must pass each criteria in the 55 ± 2 miles per hour series of impacts to be acceptable

9-17.4 Pre-approval

In order for a particular model of flexible guide post to become pre-approved, the following conditions must be met:

1. The manufacturer must submit a written request for pre-approval along with samples for each model to be tested to: State Materials Engineer, Department of Transportation Materials Laboratory, P.O. Box 47365, Olympia, WA 98504-7365. Requests shall identify the model for which approval is being requested. Samples shall be complete with reflective panel attached, and shall be accompanied by the manufacturer's written installation procedures.
2. The guide posts will be field impact tested by the State Materials Laboratory to verify compliance with these specifications.
3. In lieu of State Materials Laboratory testing, the Lab will accept the results of pre-approved testing performed by the manufacturer or other agencies under the following conditions:
    a. The State Materials Laboratory is informed of the pre-approval testing sufficiently in advance in order to attend and observe. Attendance will be at the discretion of the Materials Laboratory.
    b. The results of the testing shall be reported in sufficient detail to enable the State Materials Laboratory to evaluate compliance with these specifications.
4. The manufacturer must submit a certified test report, including test data developed by an approved testing laboratory, which demonstrates that the guide post complies with the requirements of these specifications. Certified test data supplied by the manufacturer shall be subject to verification by appropriate tests conducted by the State Materials Laboratory.

Frequency of field testing, evaluation, and pre-approval updating shall be at the sole discretion of the State Materials Laboratory.

9-18 PRECAST TRAFFIC CURB AND BLOCK TRAFFIC CURB

9-18.1 Precast Traffic Curb

9-18.1(1) Aggregates and Proportioning

The cement, fine and coarse aggregate, and reinforcing steel to be used in the manufacture of precast concrete traffic curb shall meet the following requirements:

1. Portland cement shall conform to the requirements of Section 9-01 except that it may be Type I Portland cement conforming to AASHTO M 85.
2. Aggregates shall conform to the requirements of Section 9-03 except that they shall be uniformly graded up to a maximum size of $^{3}/_{8}$-inch and shall contain sufficient fine fractions to permit securing the type of surface finish specified herein. The aggregate shall be approved by the Materials Laboratory before it is used.
3. Reinforcing steel shall conform to the requirements of Section 9-07.1.
4. The cement concrete mix shall be composed of not less than 1 part Portland cement to approximately 2 parts of fine aggregate and $3^{1}/_{4}$ parts of coarse aggregate adjusted to secure proper workability. The Contractor will be allowed to use a different concrete mix if approved by the Engineer, provided that it develops not less than 4,000 psi compressive strength when tested at the age of 28 days.

9-18.1(2) Mixing

The mixers shall be kept in good repair and be equipped with an automatic timing device and a positive device for regulating the quantity of water added to each batch. Such a device must be approved by the Engineer before use.

After all materials, including water, have been placed in the mixer, the materials shall be mixed for a period of not less than $1^{3}/_{4}$ minutes, or as much longer as may be necessary to produce a thorough and uniform mixture of the concrete. No water shall be added to any batch after the completion of the initial mixing period. Each batch of concrete shall be completely emptied from the mixer before placing more materials in it. A batch which has not been placed within 30 minutes from the time water was first added shall not be used.

The amount of water in the concrete shall be kept at a minimum consistent with the manufacture of dense curb, free from air bubbles and surface defects in excess of the tolerance limits specified.

9-18.1(3) Forms

Forms shall be of concrete or steel. The use of forms or molds made of plaster of paris, wood, or other absorptive material will not be permitted.

Bulkheads shall be tight fitting so that there is no leakage of mortar between the bulkhead and form.

The materials and methods used for lubricating the forms shall be such that they will not result in discoloration of the curb at any time. A minimum quantity of lubricant shall be used and all excess lubricant shall be removed.

9-18.1(4) Placing Concrete

The concrete shall be consolidated by external vibration, or by other means if approved by the Engineer, to produce a dense concrete throughout, having a minimum of air bubbles and honeycombing.

Reinforcing steel shall be placed and maintained in its proper position as shown in detail drawings.

Curb or buttons shall not be manufactured in an atmospheric temperature of less than 50ºF.

9-18.1(5) Removal of Forms

The curb shall be removed from the molds or forms in accordance with the instructions or by some other method acceptable to the Engineer.

The loosening of the curb from the molds shall be carefully performed to avoid excessive shock and straining of the curb. When, in the opinion of the Engineer, undue shock is required to remove the curb from the molds, the stripping operation shall be deferred until such time as the curb may be removed without breakage.

9-18.1(6) Curing Concrete

Immediately after the concrete has been placed and consolidated in the mold, each unit shall be placed in a curing room fitted with water sprays and maintained at a relative humidity of not less than 90 percent and a temperature of not less than 60ºF, nor more than 100ºF. Each unit shall remain in the curing room for a period of not less than 10 days, except that if Type III cement is used, the period in the curing room may be reduced to 5 days.

9-18.1(7) Finish

The curb shall have a smooth, glassy finish on all exposed surfaces.

Excess honeycombing in the back of the curb may be cause for rejection of the curb. Honeycombing areas in the back of the curb which, in the opinion of the Engineer, are not detrimental to the curb need not be patched. The workmanship of the bottom finish shall be such that no mechanical interlocking of the mortar bed and the curb bottom or anchor groove will occur.

9-18.1(8) Surface Treatment

As soon as the units have been taken out of the curing room and thoroughly surface dried to a depth of at least $^1/_4$-inch, two coats of a water repellent compound, meeting the requirements of Section 9-18.4, shall be brush applied. When the first coat has dried, the second coat of water repellent compound shall be applied.

9-18.1(9) Dimensions and Shape

The curb shall conform to the dimensions and shape shown in the Plans within a tolerance of $^1/_4$-inch in length and $^1/_8$-inch in alignment.

9-18.1(10) Curb Lengths

Curb lengths shall be in accordance with the Standard Plans, except in special cases where different lengths are specified. Circular curbing shall be made only for such radii as called for in the detail plans.

9-18.1(11) Defective Curb

Not more than 2 percent of the top area in any one piece of curb shall be defective, and not more than 5 percent of the total length of the top corners of reflecting faces in any one piece of curb shall be broken or rounded. There shall be not more than 50 holes in any linear foot of curb. All curb having defects in excess of any of the above will be rejected immediately upon inspection after removal from the forms. However, failure to reject the curb at that time will not ensure its final acceptance. Ninety percent of the curb laid shall not have more than 10 percent of the maximum allowable number of defects specified above.

An air hole shall be defined as any hole $^1/_8$-inch or larger in diameter or depth.

All defects within the limits permitted, apparent upon removal of forms, shall be repaired immediately.

The sum of the length of the lines of discoloration caused by a cracked mold in any one piece of curb shall not exceed 50 percent of the length of the curb, and the maximum length of any single line of discoloration shall not exceed 18-inches. 75 percent of the curb laid shall be entirely free from lines of discoloration. The employment of heat to obliterate lines of discoloration will not be permitted. The process used to obliterate lines of discoloration shall be subject to the approval of the Engineer.

The repairing of molds which are chipped or broken shall be done in a manner that the broken or chipped areas will not be apparent on the curb made in those molds.

All curb in which surface checking develops during the first five days after manufacture will be rejected.

Hidden air holes at or immediately below the exposed surface of the curb, in excess of the limits specified that are disclosed by testing the surface by means of a rubber hammer will be cause for rejection of the curb.

All curb in which cracking is in evidence immediately after removal from the molds will be rejected. A crack is defined as any separation of the concrete of a continuous length greater than 3-inches.

All curb which varies in dimensions, alignment, or surface contour in excess of the tolerance specified will be rejected.

Failure to comply with the plans, specifications, or instructions of the authorized representative of the Contracting Agency in the manufacture and laying of any curb will be cause for rejection of such curb.

9-18.1(12) Repairing Curb

Curb having defects which are not sufficient cause for its rejection shall be neatly repaired immediately after removal from the molds in a manner subject to the approval of the Engineer. However, no patching or other repairs shall be made without the permission of the Engineer. Patches shall be undercut if, in the opinion of the Engineer, this operation is necessary to achieve a satisfactory patch.

All holes larger than $^1/_{16}$-inch diameter in the exposed surface of acceptable curb or buttons shall be filled with cement mortar.

9-18.1(13) Identification Marking

The date of manufacture, the length, and identification number corresponding to the detail layout shall be marked in black paint on the back or end of each piece of curb.

Rejected curb shall be marked on the back or end surfaces in a practical and semi-permanent manner to identify each cause of rejection.

9-18.1(14) Shipping

No unit of curb shall be shipped from the manufacturing plant prior to 21 days after manufacture, except, however, that if Type III cement has been used, the units may be shipped 14 days after manufacture.

9-18.1(15) Sampling and Inspection

The Contractor shall submit, for the approval of the Engineer, an advance sample of curb which shall be at least equivalent in color, surface texture, and bottom finish to the standard as set forth in these Specifications. No repairing of any kind shall be done on the advance sample. Upon approval, the advance sample shall be stored at the plant or site of manufacture in a location readily accessible to the Inspector where there is adequate daylight for examination. The advance sample shall be protected from damage and discoloration and shall be used as a standard of comparison for color, surface texture, and bottom finish for all curb manufactured. All curb furnished shall be equivalent in the foregoing respects.

The inspection at the plant will be made just prior to shipment, at which time examination will be made of the alignment, contour, color, cracks, surface damage or discoloration, broken corners or edges, and any other defects which may have developed, and to check the laboratory test reports for strength. However intermediate inspections may be made to determine surface checking and hidden air holes if it is impractical to examine for these defects at the final inspection.

9-18.2 Vacant

9-18.3 Block Traffic Curb

In construction of the block traffic curb, the Contractor shall have the option of using either length block shown in the plans, provided the same length block is used throughout the entire project.

The curb units shall be made from Portland cement and high quality sand and gravel, the proportions of which will be left to the discretion of the producer as long as the unit develops a minimum compressive strength of 1,600 psi at 28 days when tested for end loading.

The proportions of sand, gravel, and cement, the type of forms used, and the method of compacting the concrete in the forms shall all be such that as dense, smooth, and uniform a surface as is practicable for a concrete masonry unit is obtained on the finished curb units. The faces that are to be exposed shall be free from chips, cracks, air holes, honeycomb, or other imperfections except that if not more than 5 percent of the curb units contain slight cracks, small chips not larger than $^1/_2$-inch, or air holes not more than $^1/_2$-inch in diameter or depth, this shall not be deemed grounds for rejection. The units used in any contiguous line of curb shall have approximately the same color and surface characteristics.

9-18.4 Water Repellent Compound

The water repellent compound shall be a clear, penetrating type, silicone resin base compound containing no filler or other material which will leave a film on the surface of the masonry after it is applied. It shall be of such consistency that it can be applied readily by brush or spray to the masonry at atmospheric temperature down to -20ºF.

The average absorption of three test specimens treated with the water repellent compound, when tested in accordance with the methods used in the State Materials Laboratory, shall not exceed 2 percent after being partially immersed in water for 72 hours immediately after curing.

The average moisture vapor transpiration (breathing) of three test specimens, when tested in accordance with the methods used in the State Materials Laboratory, shall be not less than 50 percent at seven days.

The water repellent compound shall be approved by the State Materials Laboratory before it is used.

9-18.5 Sodium Metasilicate

Sodium metasilicate shall comply with ASTM D 537.

9-19 PRESTRESSED CONCRETE GIRDERS

9-19.1 Aggregates and Proportioning

The concrete for prestressed girders shall have the minimum compressive strengths as specified in the Plans. Aggregates used in the mix shall conform to the following: Coarse aggregate shall be in accordance with Section 9-03.1(4); and fine aggregate shall be in accordance with Section 9-03.1(2), Class I or Class II. The manufacturer may revise the grading of the coarse aggregate provided that the concrete mix design is qualified with the modified gradation.

The Contractor shall submit for approval a proposed mix design for each design strength. Included shall be evidence satisfactory to the Engineer that the proposed mix design will meet design requirements. Approval of the mix design will not preclude any requirements for the concrete placed in the girders.

The concrete mix shall be prepared and placed in accordance with the appropriate sections of Section 6-02.

Water used in mixing the concrete shall conform to the requirements of Section 9-25.1.

Cement shall conform to the requirements of Section 9-01.

Chemical admixtures shall conform to the provisions of Section 9-23.7.

The total chloride ion (C1-) content of the mixed concrete, expressed as a percent by mass of cement, shall not exceed 0.06 percent.

9-19.2 Reinforcement

Reinforcement shall meet the requirements of Section 9-07 and shall be placed in accordance with the requirements of Section 6-02.3(24).

9-20 CONCRETE PATCHING MATERIAL

9-20.1 Patching Material

Concrete patching material will be prepackaged mortar extended with aggregate. The amount of aggregate for extension shall conform to the manufacturer's recommendation.

9-20.2 Specifications

Patching mortar and patching mortar extended with aggregate shall contain cementitious material and meet the requirements of Sections 9-20.2(1) and 9-20.2(2). The Manufacturer shall use the services of a laboratory that has an equipment calibration verification system and a technician training and evaluation process per AASHTO R-18 to perform all tests specified in Section 9-20.

9-20.2(1) Patching Mortar

Patching mortar shall conform to the following requirements:

Patching Mortar	ASTM Test Method	Specification
Compressive Strength		
at 3 hours	C 39	Minimum 3,000 psi
at 24 hours	C 39	Minimum 5,000 psi
Length Change		
at 28 days	C 157	0.15 percent maximum
Total Chloride Ion Content	C 1218	1 lb/yd3 maximum
Bond Strength		
at 24 hours	C 882 (As modified by C 928, Section 8.5)	Minimum 1,000 psi
Scaling Resistance (at 25 cycles of freezing and thawing)	C 672 (As modified by C 928, Section 8.4)	1 lb/ft2 maximum

9-20.2(2) Patching Mortar Extended with Aggregate

Patching mortar extended with aggregate shall meet the following requirements:

Patch Mortar Extended with Aggregate	ASTM Test Method	Specification
Compressive Strength		
at 3 hours	C 39	Minimum 3,000 psi
at 24 hours	C 39	Minimum 5,000 psi
Length Change		
at 28days	C 157	0.15 percent maximum
Bond Strength		
at 24 hours	C 882 (As modified by ASTM C 928, Section 8.5)	Minimum 1,000 psi
Scaling Resistance (at 25 cycles of freezing and thawing)	C 672	2 Maximum Visual Rating
Freeze thaw	C 666	Maximum expansion 0.10% Minimum durability 90.0%

9-20.2(3) Aggregate

Aggregate used to extend the patching mortar shall meet the requirements of Section 9-03.1(4) and be AASHTO Grading No. 8. A Manufacturers Certificate of Compliance shall be required showing the aggregate source and the gradation. Mitigation for Alkali Silica Reaction (ASR) will not be required for the extender aggregate used for concrete patching material.

9-20.2(4) Water

Water shall meet the requirements of Section 9-25.1. The quantity of water shall be within the limits recommended by the manufacturer

9-21 RAISED PAVEMENT MARKERS (RPM)

9-21.1 Raised Pavement Markers Type 1

Markers Type 1 shall be plastic or thermoplastic markers composed of thermosetting resins, pigments, and inert ingredients and be of uniform composition. Markers shall not contain glass.

9-21.1(1) Physical and Chemical Properties

The markers shall be of uniform composition and free from surface irregularities, cracks, checks, chipping, peeling, spalling, crazing, and other physical damage interfering with appearance, application, or durability.

The markers shall be precast in the form of a single based spheroidal segment terminating in a rounded or squared shoulder. Markers shall be white or yellow.

The markers shall meet the following requirements:

Property	Unit	Thermoplastic Markers	Plastic Markers
Mass	grams	N/A	125 min.
Height	inches	0.65-0.78	0.65-0.78
Diameter/Width	inches	3.85-4.05	3.85-4.05
Shoulder height	inches	0.08-0.22	0.08-0.22
Planeness of base:			
Concavity	inches	0.05 max.	0.05 max.
Convexity	inches	0.05 max.	0.05 max.
Reflectance (white only)	%MgO	80 min.	80 min.
Impact resistance	inch-pound	15 min.	15 min.
Titanium Dioxide (white only)	% by weight	N/A	21 min.

The markers passing laboratory tests will be field tested for approval. The field tests will include installation with control markers to determine relative adhesion and durability characteristics.

9-21.2 Raised Pavement Markers Type 2

The marker housing shall contain reflective faces as shown in the Plans to reflect incident light from either a single or opposite directions.

9-21.2(1) Physical Properties

The markers shall be not less than 4.0-inches nor more than 5.0-inches in width, and not more than 0.75-inch in height.

The outer surface of the marker housing shall be smooth except for the purpose of identification.

The base of the markers shall be substantially free from gloss or substances that may reduce its bond to adhesive.

The markers passing laboratory tests will be field tested for approval. The field tests will include installation with control markers to determine relative adhesion and durability characteristics.

9-21.2(2) Optical Requirements

1. **Definitions:** Horizontal entrance angle shall mean the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the marker.

   Observation angle shall mean the angle at the reflector between observer's line of sight and direction of the light incident on the reflector.

   Specific intensity (S.I.) shall mean candle power of the returned light at the chosen observation and entrance angles for each foot-candle of illumination at the reflector on a plane perpendicular to the incident light.

2. **Optical Requirements:** The specific intensity of each reflecting surface at 0.2 degrees observation angle shall be not less than the following when the incident light is parallel to the base of the marker.

Hor. Ent. Angle	S.I.
0	3.0
20	1.2

   Yellow reflectors shall be not less than 60 percent and red reflectors not less than 25 percent of the above values.

3. Optical Testing Procedure: a random lot of markers will be tested. The markers to be tested shall be located with the center of the reflecting face at a distance of 5-feet from a uniformly bright light source having an effective diameter of 0.2-inch.

   The photocell width shall be 0.05-inch. It shall be shielded to eliminate stray light. The distance from light source center to the photocell center shall be 0.21-inch. If a test distance of other than 5-feet is used, the source and receiver dimensions and the distance between source and receiver shall be modified in the same proportion as the test distance.

   Failure of more than 4 percent of the samples shall be cause for rejection of the lot.

9-21.2(3) Strength Requirements

Markers shall support a load of 2,000 pounds as applied in the following manner:

A marker shall be centered over the open end of a vertically positioned hollow metal cylinder. The cylinder shall be 1-inch high with an internal diameter of 3-inches and wall thickness of $^1/_4$-inch. The load shall be slowly applied to the top of the marker through a 1-inch diameter by 1-inch high metal plug centered on the top of the marker.

Failure shall constitute either a breakage or significant deformation of the marker at any load of less than 2,000 pounds.

9-21.3 Raised Pavement Markers Type 3

Raised pavement markers Type 3 shall be extruded from high impact thermoplastic material which has been ultra-violet radiation stabilized and shall meet the following requirements:

Impact resistance	15-inch-lbs., min.
Reflectance (White Only)	80% min.
Concavity & Convexity	
Transverse	$^{1}/_{16}$-inch, max.
Longitudinal	$^{1}/_{8}$-inch, max
Base Width	4″
Length	6″, 8″, 10″ or 12″
Height	0.60-0.75″
Shoulder height	0.08-0.20

The ends shall be beveled from the top of the shoulder edge at a slope of 1:1 nominal.

9-22 MONUMENT CASES

9-22.1 Monument Cases, Covers, and Risers

Castings for monument cases, covers, and risers shall be gray iron castings conforming to the requirements of AASHTO M 105, Class 30B. The cover and seat shall be machined so as to have perfect contact around the entire circumference and full width of bearing surface. Dipping, painting, welding, plugging, or repairing defects will not be permitted.

9-23 CONCRETE CURING MATERIALS AND ADMIXTURES

9-23.1 Sheet Materials for Curing Concrete

Sheet materials for curing concrete shall meet the requirements of AASHTO M 171, Sheet Materials for Curing Concrete, except that only white reflective type shall be used.

9-23.2 Liquid Membrane-Forming Concrete Curing Compounds

Liquid membrane-forming compounds for curing concrete shall conform to the requirements of AASHTO M 148 (ASTM C 309) Type 1D or 2, Class A or B, except that the moisture loss when tested in accordance with WSDOT Test Method 814 shall be 2.50 grams for all applications.

Each lot of liquid membrane-forming curing compound shall be sampled at the project site and tested for acceptance. Liquid membrane-forming curing compound shall not be used in the absence of satisfactory test results.

9-23.3 Vacant

9-23.4 Vacant

9-23.5 Burlap Cloth

Burlap cloth shall meet the requirements of AASHTO M 182, Class 4.

9-23.6 Admixture for Concrete

Admixtures for use in concrete shall meet the following specifications:

Admixture	Specification	
Air-entraining	AASHTO M 154	ASTM C 260
Water Reducing	AASHTO M 194 Type A	ASTM C 494 Type A
Set Retarding	AASHTO M 194 Type B	ASTM C 494 Type B
* Accelerating	AASHTO M 194 Type C	ASTM C 494 Type C
Water Reducing/ Set Retarding	AASHTO M 194 Type D	ASTM C 494 Type D
* Water Reducing/	AASHTO M 194 Type E	ASTM C 494 Type E
Accelerating High Range Water Reducing	AASHTO M 194 Type F and G	ASTM C 494 Type F and G

* Accelerating admixtures are only allowed in Portland Cement Concrete Pavement per Section 5-05, Cement Concrete Pavement and Section 5-05.3(1) Concrete Mix Designs for Paving.

In addition to the above specifications, admixtures proposed for use shall contain less than one percent chloride ion (Cl-) by weight of admixture and only non-chloride accelerating admixtures shall be used.

Acceptance of admixtures will be based on Manufacturer's Certificate of Compliance.

If required by the Engineer, admixtures shall be sampled and tested before they are used.

Samples shall be submitted for testing 10 days prior to use.

9-23.7 Air Entraining and Chemical Admixtures for Precast Prestressed Concrete

Air entraining admixture shall meet the requirements of AASHTO M 154. Acceptance will be on the basis of a Manufacturer's Certification of Compliance.

If required by the Engineer, the air entraining admixture shall be sampled and tested by the Materials Laboratory before use.

Chemical admixtures shall conform to the requirements of AASHTO M 194, Type A, B, D, or F. Approval of specific admixture products shall be required as a part of the annual approval of prestressed fabricators. Chloride ion content of chemical admixtures shall not exceed one percent by weight.

Acceptance will be on the basis of a Manufacturer's Certification of Compliance.

If required by the Engineer, the admixture shall be sampled and tested by the Materials Laboratory before use.

9-23.8 Waterproofing

Concrete made with waterproofing admixtures shall have a percent absorption after immersion and boiling of less than 5.0 percent at seven days and a volume of permeable voids less than 11.0 percent at seven days per ASTM C 642. The Contractor shall submit evidence in the form of test results showing compliance with these specifications, when they submit their concrete mix design.

If the concrete requires air entrainment, the Contractor shall also submit evidence to the Engineer that the admixture will not adversely effect the air void system of the hardened concrete. Test results complying with ASTM C 457 shall be provided as evidence to satisfy this requirement.

9-23.9 Fly Ash

Fly ash shall conform to the requirements of AASHTO M 295 Class C or F including optional chemical requirements as set forth in Table 2 and with a further limitation that the loss on ignition shall be a maximum of 1.5 percent.

9-23.10 Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag shall meet the requirements of AASHTO M 302, Grade 100 or Grade 120. The grade of the ground granulated blast furnace slag, the source, and type of manufacturing facility shall be certified on the cement mill test certificate.

9-23.11 Microsilica Fume

Microsilica Fume shall conform to the requirements of AASHTO M 307. The optional physical requirement for Reactivity with Cement Alkalies set forth in Table 3 will be required when Microsilica Fume is being used as an ASR mitigation measure.

9-24 PLASTIC WATERSTOP

9-24.1 Material

The waterstops shall be fabricated from a plastic compound, the basic resin of which shall be polyvinyl chloride. The compound shall contain any additional resins, plasticizers, inhibitors, or other material such that when the material is compounded, it shall meet the performance requirements given in these Specifications.

Single-pass reworked material of the same composition generated from the fabricator's waterstop production may be used. No reclaimed polyvinyl chloride shall be used.

All waterstops shall be molded or extruded in such a manner that any cross section will be dense, homogeneous, and free from porosity and other imperfections.

The waterstops shall be symmetrical in shape, nominal 4-inches in width, by $^{3}/_{16}$-inch thick, and a minimum of four ribs on each side of the bulb. The bulb thickness and diameter shall be as noted in the plans.

9-24.1(1) Tests of Material

The waterstops shall meet all of the physical and other test requirements of this material as defined in the Corps of Engineers Specifications for Polyvinyl Chloride Water Stop CRD-C572, except that the tear resistance of the material shall be not less than 160 pounds per inch. The Contractor shall furnish such sample material as required by the Engineer for the purpose of making tests.

9-25 WATER

9-25.1 Water for Concrete

Water for mortar or concrete shall be clear and apparently clean. If the water contains substances that cause discoloration, unusual or objectionable smell or taste, or other suspicious content, the Engineer may require the Contractor to provide test results documenting that the water meets the physical test requirements and chemical limits described in ASTM C94M Section 5.1.3, Tables 2 and 3.

Water from mixer washout operations may be used in concrete provided it meets or exceeds the above criteria as well as the following additional requirements:

1. Concrete with water from mixer washout operations shall not be used in bridge roadway deck slabs, flat slab bridge superstructures, modified concrete overlays, or prestressed concrete.
2. Specific Gravity shall not exceed 1.07.
3. Alkalies, expressed as [Na2O+0.658 K2O], shall not exceed 600 ppm.
4. Shall be free of coloring agents.
5. If the wash water contains admixtures from different manufacturers, the Contractor shall provide evidence that the combination of admixtures are compatible and do not adversely affect the air void system of the hardened concrete as per Section 6-02.3(3).
6. All tests to verify that the physical and chemical requirements are met, shall be conducted on the following schedule:
   a. The physical requirements shall be tested on weekly intervals for four weeks and thereafter on monthly intervals.
   b. The chemical requirements shall be tested on monthly intervals.
   c. The specific gravity shall be determined daily in accordance with ASTM D 1429, Test Method D.

The Contractor shall use the services of a Laboratory that has a equipment calibration/verification system, and a technician training and evaluation process per AASHTO R-18 to conduct all tests. The laboratory shall use testing equipment that has been calibrated/verified at least once within the past 12 months to meet the requirements of each test procedure in accordance with the appropriate section of AASHTO R-18. Documentation of tester qualifications and equipment verification records shall be maintained and available for review by the Contracting Agency upon request. Agency reviews of the laboratory facility, testing equipment, personnel, and all qualification, calibration, and verification records will be conducted at the Contracting Agency's discretion.

9-25.2 Water for Plants

Water for plants shall not contain dissolved or suspended matter which will be harmful to the plant material on which it is to be used.

9-26 EPOXY RESINS

9-26.1 Epoxy Bonding Agents

9-26.1(1) General

Epoxy bonding agents shall be 2-component epoxy resin-base systems that meet the requirements of ASTM C 881, shall be furnished in the type, grade, and class specified, and shall meet the requirements below. When not specified, an appropriate grade and class shall be selected for the particular application. Epoxy bonding agents for patching external concrete shall be concrete-gray in color.

9-26.1(1)A Type I and Type IV

Epoxy bonding agents used for bonding hardened concrete to hardened concrete and other materials shall be Type I for non-load bearing applications and Type IV for load bearing applications.

9-26.1(1)B Type II and Type V

Epoxy bonding agents used for bonding freshly mixed concrete to hardened concrete shall be Type II for non-load bearing applications and Type V for load bearing applications.

9-26.1(1)C Type III

Epoxy bonding agents used for bonding skid-resistant materials to hardened concrete and as a binder in epoxy mortars and epoxy concretes used on traffic bearing surfaces shall be Type III.

9-26.1(2) Packaging and Marking

The components of the epoxy system furnished under these Specifications shall be supplied in separate containers that are non-reactive with the materials contained. The contents of each container shall be such that when the container contents are combined, a properly proportioned final mixture results.

Containers shall be identified as “Component A” (Contains the Epoxy Resin) and “Component B” (Contains the Curing Agent) and shall show the type, grade, class and mixing directions as defined by these Specifications. Each container shall be marked with the name of the manufacturer, the lot or batch number, the date of packaging, and the quantity contained in pounds or gallons.

Potential hazards shall be so stated on the package in accordance with the Federal Hazardous Products Labeling Act and State of Washington, Department of Labor and Industries Regulations for Shipment of Hazardous Products.

9-26.1(3) Certification

If requested by the Contracting Agency, the manufacturer of the epoxy system shall certify that components A and B meet the requirements of this specification before a sample will be accepted for testing by the Contracting Agency. The Manufacturer’s Certificate of Compliance shall be furnished in accordance with Section 1-06.3.

9-26.1(4) Rejection

Except as noted otherwise, the entire lot of both components may be rejected if samples submitted for test fail to meet any requirements of this specification.

9-26.1(5) Acceptance

Acceptance of the Epoxy Bonding Agents for use on the project shall be based on a passing test report from the State Materials Laboratory.

9-26.2 Epoxy Adhesive for Lane Markers

9-26.2(1) General

Epoxy adhesives for lane markers shall meet the requirements of AASHTO M 237 for Type II - Standard Setting, High Viscosity, Epoxy Adhesive. In lieu of the square base test specimen molds for the Slant Shear Strength test specified in AASHTO M, cylindrical molds in accordance with ASTM D882 may be used.

9-26.2(2) Packaging and Marking

Packaging and Marking of Epoxy Adhesive for Lane Markers shall meet the requirements of Section 9-26.1(2).

9-26.2(3) Certification

Certification of Epoxy Adhesive for Lane Markers shall meet the requirements of Section 9-26.1(3).

9-26.2(4) Rejection

Rejection of Epoxy Adhesive for Lane Markers shall meet the requirements of Section 9-26.1(4).

9-26.2(5) Acceptance

Acceptance of each lot of the Epoxy Adhesive for Lane Markers for use on the project shall be based on a Manufacturer's Certificate of Compliance.

9-26.3 Epoxy Grout/Mortar/Concrete

9-26.3(1) General

This specification shall apply to epoxy grout, epoxy mortar and epoxy concrete for traffic and non-traffic bearing applications. Epoxy grout/mortar/concrete shall consist of an epoxy bonding agent and an aggregate component.

Prepackaged epoxy grout/mortar/concrete shall be prepared from a ready-to-mix epoxy bonding agent/aggregate system supplied by a manufacturer in kit form.

Non-prepackaged epoxy grout/mortar/concrete shall be prepared from an epoxy bonding agent and an aggregate component that is clean, surface dry and inert and that is of a quality and gradation suitable for Portland cement mortar or concrete. Aggregate meeting the requirements of Section 9-03.1(2) will be satisfactory. Epoxy grout/mortar/concrete for patching external concrete shall be concrete-gray in color.

9-26.3(1)A Traffic Bearing Applications

Epoxy grout/mortar/concrete for traffic bearing applications shall have a seven-day compressive strength of not less than 2500 psi when tested in accordance with ASTM C579. Epoxy bonding agent shall be Type III as described in Section 9-26.1(1)C.

9-26.3(1)B Non-Traffic Bearing Applications

Epoxy grout/mortar/concrete for non-traffic bearing applications shall have a seven-day compressive strength of not less than 4000 psi when tested in accordance with ASTM C579. Epoxy bonding agent shall be Type I, II, IV, or V as appropriate for intended use as described in Section 9-26.1(1)A and Section 9-26.1(1)B.

9-26.3(2) Packaging and Marking

Packaging and Marking of the epoxy bonding agent component of epoxy grout/mortar/concrete shall meet the requirements of Section 9-26.1(2).

9-26.3(3) Certification

Certification of the epoxy bonding agent component of epoxy grout/mortar/concrete shall meet the requirements of Section 9-26.1(3).

9-26.3(4) Rejection

Rejection of the epoxy bonding agent component of epoxy grout/mortar/concrete shall meet the requirements of Section 9-26.1(4).

9-26.3(5) Acceptance

Acceptance of the epoxy grout/mortar/concrete material for use on the project shall be based on a passing test report from the State Materials Laboratory.

9-27 CRIBBING

9-27.1 Vacant

9-27.2 Vacant

9-27.3 Gabion Cribbing

9-27.3(1) Gabion Fabric

Gabions may be fabricated from either hexagonal twisted wire mesh or from welded wire mesh. Only one type of mesh and protective coating shall be used throughout a structure.

Baskets shall be furnished in the required dimensions with a dimensional tolerance of plus or minus 5 percent.

Wire for construction of gabions shall be either galvanized steel wire conforming to ASTM A 641, Class 3, Soft Temper, or aluminized steel wire conforming to ASTM A 809, Soft Temper. The wire shall have a minimum tensile strength of 60,000 psi when tested in accordance with ASTM A 370.

9-27.3(2) Gabion Baskets

Gabion baskets 1-foot or greater in the vertical dimension shall have mesh openings with nominal dimensions not to exceed $4^1/_2$-inches and the maximum area of any mesh opening shall not exceed 10 square inches.

1. Hexagon Twisted Wire Mesh
   a. Wire for galvanized or aluminized hexagonal twisted wire mesh shall be nominal sized 0.120-inch galvanized steel wire or aluminized steel wire.
   b. Hexagonal wire mesh be formed from galvanized or aluminized wire in a uniform hexagonal pattern with nonraveling double twist. The perimeter edges of the mesh for each panel shall be tied to a selvage wire of the same composition as the body mesh and have a minimum diameter of 0.150-inch so that the selvage is at least the same strength as the body of the mesh.
2. Welded Wire Mesh
   a. Welded wire mesh shall be fabricated from galvanized steel wire having a diameter of 0.106-inch. Wire shall be galvanized prior to fabrication.
   b. Welded wire mesh shall be formed in a uniform square pattern with openings 3-inches by 3-inches with a resistance weld at each connection in accordance with ASTM A 185.
   c. If required, a PVC coating shall be fusion bonded onto the welded wire mesh to provide a nominal coating thickness of 0.0216-inch per side with a minimum of 0.0150-inch.
3. PVC Coating (for welded wire mesh only)

   Acceptance of PVC coating material shall be by certified test reports of an independent laboratory. The initial properties of PVC coating material shall have a demonstrated ability to conform to the following requirements:
   a. Specific Gravity — In the range of 1.2 to 1.4, when tested according to ASTM D 792.

b. Tensile Strength — Not less than 2,275 psi, when tested according to ASTM D 638.

c. Modulus of Elasticity — Not less than 1,980 psi at 100 Strain, when testing according to ASTM D 638.

d. Hardness — Shore "A" not less than 75 when tested according to ASTM D 2240.

e. Brittleness Temperature — Not higher than 15ºF when tested according to ASTM D 746.

f. Resistance to Abrasion — The percentage of the mass loss shall be less than 12 percent when tested according to ASTM D 1242, Method B at 200 cycles, CSI-A Abrader Tape, 80 Grit.

g. Salt Spray Exposure and Ultraviolet Light Exposure – The PVC shall show no effect after 3,000 hours of salt spray exposure according to ASTM B 117. The PVC shall show no effect of exposure to ultraviolet light with test exposure of 3,000 hours using apparatus Type E and 63°C, when tested according to Practice D 1499 and Practice G 23. After the salt spray test and exposure to ultraviolet light as specified above, the PVC coating shall not show cracks, blister, split, nor show a noticeable change of color. In addition, the specific gravity, tensile strength, modulus of elasticity, and resistance to abrasion shall not change more than 6, 25, 25, and 10 percent respectively from their initial values.

9-27.3(3) Gabion Mattresses

Gabion baskets less than 1-foot in the vertical dimension shall have mesh openings with nominal dimensions not to exceed 3.3-inches, and the maximum area of any mesh opening shall not exceed 6 square inches.

1. Hexagonal Twisted Wire Mesh

   a. Wire for galvanized or aluminized hexagonal twisted wire mesh shall be nominal sized 0.086-inch galvanized steel wire or aluminized steel wire.

   b. Hexagonal wire mesh shall be formed from galvanized or aluminized wire in a uniform hexagonal pattern with nonraveling double twisted. The perimeter edges of the mesh for each panel shall be tied to a selvage wire of the same composition as the body mesh and have a minimum diameter of 0.1062-inch so that the selvage is at least the same strength as the body of the mesh.

2. Welded Wire Mesh

   a. Welded wire mesh shall be fabricated from galvanized steel wire having a diameter of 0.080-inch. Wire shall be galvanized prior to fabrication.

   b. Welded wire mesh shall be formed in a uniform rectangular pattern with openings $1^1/_2$-inches by 3-inches with a resistance weld at each connection in accordance with ASTM A 185.

   c. If required, a PVC coating shall be fusion bonded onto the welded wire mesh to provide a nominal coating thickness of 0.0216-inch per side with a minimum of 0.0150-inch. The PVC coating shall be in conformance with Section 9-27.3(2).

9-27.3(4) Fasteners for Basket Assembly

The lacing wire shall be a nominal sized 0.0866-inch galvanized steel wire or aluminized steel wire. Lacing wire shall have the same coating as the basket mesh.

Spiral binders, if used for joining welded wire panels shall be formed from 0.106-inch nominal diameter steel wire with a 3-inch pitch having the same specifications and coating as the wire mesh. Lacing wire may be used in lieu of spiral binders.

Alternate fasteners for basket assembly shall remain closed when subjected to a 600 pound tensile force when confining the maximum number of wires to be confined. Installation procedures and test results for alternate fasteners shall be submitted for approval.

Internal connecting wires shall be the same as required for lacing wire. Alternate stiffeners acceptable to the gabion manufacturer may be used.

9-27.3(5) Nonraveling Construction

The wire mesh shall be fabricated in a manner to be nonraveling. This is defined as the ability to resist pulling apart at any of the connections forming the mesh when a single strand in a section of mesh is cut.

9-27.3(6) Stone

Stone for filling gabions shall have a Degradation Factor of at least 30. The stone shall be dense enough to pass the unit weight test described in Section 8-24.3(3)F. Stone shall meet the following requirements for gradation:

Sieve Size	Percent Passing
8″ square	100
6″ square	75-90
4″ square	0-10
% Fracture	75 min.

All percentages are by weight.

9-28 SIGNING MATERIALS AND FABRICATION

9-28.1 General

Unless noted otherwise in the Plans, permanent signs shall be constructed of sheet aluminum. Permanent signs which measure 36-inches or less on a side and are to be mounted on a single post may be constructed of single 0.135-inch fiberglass reinforced plastic panels. Sign overlay panels may be either 0.050-inch aluminum or 0.075-inch fiberglass reinforced plastic panels. All signs, except internally illuminated signs, shall be reflectorized.

See ASTM D 4956 for reflective sheeting type designations. Standard control signs and guide sign borders, letters, numerals, symbols, shields, and arrows shall be in accordance with the "Washington State Sign Fabrication Manual."

All STOP, YIELD, DO NOT ENTER, WRONG WAY, FREEWAY ENTRANCE, and HIGHWAY ENTRANCE signs shall be constructed entirely of Type III or IV reflective sheeting. All M series, I series, and D-10 series signs and all signs with blue or brown backgrounds shall be constructed entirely of Type II reflective sheeting unless otherwise specified. Background reflective sheeting for all other signs shall be as noted in the Plans. Sign legends for all other signs shall be constructed of Type III or IV reflective sheeting. Sign legends include: borders, letters, numerals, symbols, shields, and arrows. Reflective legend sheeting types shall not be mixed on individual signs.

9-28.1(1) Basis for Acceptance

Reflective sheeting shall be accepted on the basis of inclusion of the material/product on the Qualified Product List or by approval of a Request for Approval of Materials. The sign fabricator shall have available for inspection a copy of the Manufacturer's Certificate of Compliance for each lot of reflective sheeting. This certificate shall verify that the reflective sheeting meets all the requirements of Section 9-28.12.

The basis for acceptance of aluminum sign blanks and panels shall be a mill test certificate from the aluminum manufacturer attesting to the correct alloy and temper of the metal supplied. At the option of the Engineer, laboratory tests may also be performed to confirm metallurgical data.

It is expressly understood that the furnishing of certificates of compliance will not relieve the Contractor from the obligation to replace materials found defective after delivery to the project, nor will they prevent the Engineer from sampling material when it arrives on the project and subjecting it to such laboratory tests as they may deem appropriate or significant.

9-28.1(2) Inspection

All signs will be inspected at the fabricator's plant before shipment to the project. The inspection shall not be made until all materials have been tested and approved. Signs without a "FABRICATION APPROVED" decal will not be installed on the project with the exception of double-faced signs which do not receive decals or fabricator's stickers.

9-28.2 Manufacturer's Identification and Date

All signs shall show the manufacturer's name and date of manufacture on the back. In addition, the width and height dimension, in inches, and the number of the sign as it appears in the Plans shall be placed using 3-inch series C black letters on the back of destination, distance, and large special signs. Hand painted numbers are not permitted.

9-28.3 Corner Radius

All regulatory and warning signs shall have rounded corners with the exception of stop signs. Information and guide signs may have square cut corners. Borders for signs having square cut corners shall have a corner radius approximately $^1/_8$ of the lesser side dimension of the sign up to a maximum radius of 12-inches. For signs with rounded corners, the borders shall be concentric with the rounded corners.

9-28.4 Extruded Windbeams and "Z" Bar

All multiple post and multiple panel signs shall be constructed and installed with horizontal extruded windbeams and "Z" bar, when required, as shown in the Plans or the Standard Plan. All bolt and rivet heads visible on the sign face shall be anodized or painted to match the sign area immediately surrounding the bolt or rivet head. Extruded windbeams and "Z" bar shall be accepted on the basis of a certificate of compliance from the manufacturer. Materials shall be as designated in Section 9-28.11.

9-28.5 Letter and Spacing Formula

Letter and arrow sizes shall be as specified in the Plans. Spacing formulas shall be those furnished by the manufacturer of the letters.

9-28.6 Destination Sign Messages

Destination sign messages, borders, shields, and symbols shall be direct applied unless otherwise noted in the sign plans. All message components shall be one piece construction unless the least dimension exceeds available sheeting widths. All components shall have smooth, sharp cut edges. Components which are torn, wrinkled, or exhibit poor workmanship, will not be permitted.

9-28.7 Process Colors

Transparent and opaque process colors used in silk screening sign messages shall be as recommended by the manufacturer. When properly applied, process colors shall perform satisfactorily for the expected life of the sheeting. Applied colors shall present a smooth surface, free from foreign material, and all messages and borders shall be clear and sharp. Sheeting shall conform to the retroreflective minimum values and color limits established for its type and color without regard to whether the color is integral to the sheeting or achieved by applying transparent colors to silver/white sheeting. There shall be no variations in color, and overlapping of colors will not be permitted.

Properly applied and cured process colors shall exhibit no blistering, bubbling, or loss of color or transparency when cleaned with a mild non-abrasive detergent solution. Minor loss of color may be detected when solvents such as kerosene, mineral spirits, heptane, or VM&P Naphtha are used to clean severely contaminated signs; e.g., paint vandalism. However, the colors shall not blister, bubble, peel, or be easily removed.

9-28.8 Sheet Aluminum Signs

Sheet aluminum signs shall be constructed of material conforming to ASTM B 209 alloy 6061-T6 or alloy 5052-H36 or H38. Alloy 5005-H34 may be used for sign overlays.

After the sheeting has been fabricated, the sheeting for all multiple panel signs shall be degreased, etched by immersion for a minimum of 5 minutes in a 6-ounce per gallon caustic etch solution at 120°F, followed, in order, by a water rinse, de-oxidation, water rinse, hot water rinse, and drying. The etching process shall produce a dull aluminum finish on both sides of the panel which will last the life of the sign. The treated panel

surface shall be compatible with the opaque and reflective sheeting to be applied in accordance with the specifications. The Contractor may use an Alodine 1200 application for single panel signs in lieu of the above treatment. Aluminum signs over 12-feet wide by 5-feet high shall be comprised of vertical panels in increments of 2, 3, or 4-feet wide. No more than one 2-foot and/or 3-foot panel may be used per sign. The Contractor shall use the widest panels possible. All parts necessary for assembly shall be constructed of aluminum, galvanized, or stainless steel in accordance with the plans. Sheet thickness shall be as follows:

Maximum Horizontal Dimension	Sheet Aluminum Thickness
Overlay panels	0.050-inch
Up to 20-inches	0.063-inch
20-inches to 36-inches, inclusive	0.080-inch
Over 36-inches (Permanent Signs)	0.125-inch

The side dimension for a diamond shaped warning sign is considered to be the maximum horizontal dimension.

Before placing aluminum in contact with untreated steel, the steel surfaces shall be protected by proper cleaning and painting with one coat of Zinc Primer A-9-73 or A-11-99 and two coats of aluminum paint D-1-57.

Metal shall be handled by device or clean canvas gloves between all cleaning and etching operations and the application of reflective sheeting.

9-28.9 Fiberglass Reinforced Plastic Signs

Fiberglass reinforced plastic signs and overlay panels shall be constructed of a fiberglass reinforced thermoset polyester laminate. The sign panel shall be acrylic modified and UV stabilized for outdoor weathering ability.

The sign panel shall be stabilized to prevent the release of migrating constituents (such as solvents, monomers, etc.) over the expected life of the sign. The sign panel shall contain no residue release agents on the surface of the laminate so neither migrating constituents or release agents will be present in amounts which will interfere with any subsequent bonding operations.

The sign panel shall not contain visible cracks, pinholes, foreign inclusions, or surface wrinkles that would affect implied performance, alter the specific dimensions of the panel, or otherwise affect its serviceability.

The sign panel surface shall be wiped clean with a slightly water dampened cloth before applying reflective sheeting.

9-28.9(1) Mechanical Properties

All mechanical properties are stated as minimum requirements. The mechanical properties are measured in both the line direction of the panel and at 90 degrees to the line as noted in the appropriate ASTM test referenced.

Mechanical Property	Ave. Min. Requirement	ASTM Test
Tensile Strength	10.0 psi × 103	D638
Tensile Modulus	1.2 psi × 106	D638
Flexural Strength	20.0 psi × 103	D790
Flexural Modulus	1.2 psi × 106	D790
Compression Strength	32.0 psi × 103	D695
Compression Modulus	1.4 psi × 106	D695
Punch Shear	13.0 psi × 103	D732

9-28.9(2) Physical Properties

Sign Panels are to be 0.135-inch thick. Overlay panels are to be 0.075-inch thick. Panel thickness tolerance shall be plus or minus 0.005-inch. Panel tolerance on nominal length and width shall be plus or minus ⅛-inch for dimensions of 12-feet or less and shall be within ⅛-inch of square per 12-feet of length when measured in accordance with ASTM D 3841.

Panels shall be manufactured with smooth surfaces on both top and bottom of the panel.

Panel flatness of a 30-inch by 30-inch panel shall be measured by hanging the panel diagonally in suspension. The maximum deflection measured diagonally, parallel and perpendicular to the panel by lines drawn through the center of the panel, shall not exceed ½-inch. The panel shall then be hung diagonally in suspension in an oven for 48 hours at 180°F. The maximum deflection shall again be measured as previously noted and shall not exceed ½-inch. All measurements shall be made when panels are at ambient temperature.

Panels shall be pigmented to a visually uniform gray color within the MunselR range of N.7.5/to N.8.5/.

Panels shall have a maximum coefficient of lineal thermal expansion of 1.8×10^{-5} in/in/°F. when tested in accordance with ASTM D696.

Panels shall be classified as to a minimum Grade II (weather resistant) panel as specified in ASTM D 3841 following 3,000 plus or minus 100 hour weatherometer test.

Panels shall contain additives designed to be less responsive to fire ignition and flame propagation. As such, the extent of burning shall not exceed 1.0-inch when tested in accordance with ASTM D 635.

Panels shall resist the impact energy of 20 foot-pounds applied with a hemispherical tipped object 1-inch in diameter.

The panels thermal stability for strength and impact resistance qualities shall not be appreciably affected over a temperature range of -65ºF to 212°F.

Fiberglass reinforced plastic panels for signs shall be accepted on the basis of a certificate of compliance from the manufacturer as outlined in Section 1-06.3.

9-28.10 Vacant

9-28.11 Hardware

Bolts, nuts, locknuts, and washers shall be of the same material for each attachment. Bolts, nuts, locknuts, and washers for signs mounted on overhead sign structures (i.e. sign bridges, cantilevers sign structures, and bridge mounted sign brackets) shall be stainless steel only.

Hardware	Specification
Bolts	ASTM F 468 2024-T4 Aluminum ASTM A 307 Steel ASTM F 593 Group 1, Condition A Stainless Steel, or ASTM A 193, Grade B8, Class 1 Stainless Steel
U-bolts	ASTM A 276 Type 304 Stainless Steel
Washers	ASTM B 209 2024-T4 Aluminum ASTM F 844 Steel ANSI B.18.22.1 Stainless Steel Alloy 304
Nuts	ASTM F 467 2024-T4 Aluminum ASTM A 563 Grade A Steel ASTM F 594 Group 1 Stainless Steel, or ASTM A 194 Grade 8 or 8A Stainless Steel
Locknuts (with nylon insert unless otherwise in the Plans)	ASTM F 467 2024-T4 Aluminum ASTM A 563 Grade A Steel ASTM F 594 Group 1 Stainless Steel, or noted ASTM A 194 Grade 8 or 8A Stainless Steel
Rivets	ASTM B 316 5052 Aluminum Alloy ASTM B 316 5056 Aluminum Alloy
Post Clips	ASTM B 179 356-T6 Aluminum
Windbeams	ASTM B 221 6061-T6 Aluminum
Angle and “Z” Bar	ASTM B 221 6061-T6 Aluminum ASTM A 36 or ASTM A 992 Steel
Strap and Mounting Bracket	ASTM A 666, Type 201 Stainless Steel

All steel parts shall be galvanized per AASHTO M 111. Steel bolts and related connecting hardware shall be galvanized per AASHTO M 232.

9-28.12 Reflective Sheeting

Type I and Type II reflective sheeting shall consist of spherical lens elements embedded within a transparent plastic having a smooth, flat outer surface. Type III and Type IV reflective sheeting shall consist of spherical or prismatic lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, weatherproof plastic having a smooth outer surface. Type V reflective sheeting shall consist of metallized microprismatic lens bonded to a flexible, smooth-surfaced, weather resistant polymeric film. Type VI reflective sheeting shall consist of unmetallized microprismatic lens formed on a flexible vinyl material. Type VII, VIII, IX and Type X Fluorescent Orange reflective sheeting shall consist of unmetallized microprismatic lens formed in a synthetic

resin and encapsulated by a flexible, transparent, weatherproof plastic having a smooth outer surface. All sheeting shall be weather resistant and have a protected pre-coated adhesive backing. Type II reflective sheeting shall contain an identifying marking, such as a water mark, which is visible after sheeting application. The marking shall not adversely affect the performance or life of the sheeting.

The reflective sheeting shall have the following minimum coefficient of retroreflection values at 0.2 degrees and 0.5 degrees observation angle expressed as average candelas per foot-candle, per square foot of material. Measurements shall be conducted in accordance with ASTM E 810.

Type I Glass Bead Retroreflective Element Material

Obs. Angle	Entrance Angle	SILVER WHITE	YELLOW	ORANGE	GREEN	RED	BLUE	BROWN
0.2°	-4°	70	50	25	9.0	14	4.0	1.0
0.2°	+30°	30	22	7.0	3.5	6.0	1.7	0.3
0.5°	-4°	30	25	13	4.5	7.5	2.0	0.3
0.5°	+30°	15	15	4.0	2.2	3.0	0.8	0.2

Type II Glass Bead Retroreflective Element Material

Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE	BROWN
0.2°	-4°	140	100	60	30	30	10	5.0
0.2°	+30°	60	36	22	10	12	4.0	2.0
0.5°	-4°	50	33	20	9.0	10	3.0	2.0
0.5°	+30°	28	20	12	6.0	6.0	2.0	1.0

Type III Glass Bead Retroreflective Element Material

Obs. Angle	Entrance Angle	SILVER WHITE	YELLOW	ORANGE	GREEN	RED	BLUE	BROWN
0.2°	-4°	250	170	100	45	45	20	12
0.2°	+30°	150	100	60	25	25	11	8.5
0.5°	-4°	95	62	30	15	15	7.5	5.0
0.5°	+30°	65	45	25	10	10	5.0	3.5

Type IV Micro Prismatic Retroreflective Element Material

Obs. Angle	Entrance Angle	WHITE	YELLOW	GREEN	RED	BLUE	BROWN
0.2°	-4°	250	170	35	35	20	7.0
0.2°	+30°	80	54	9	9	5.0	2.0
0.5°	-4°	135	100	17	17	10	4.0
0.5°	+30°	55	37	6.5	6.5	3.5	1.4

Type V Metallized Micro Prismatic Retroreflective Element Material							
Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE
0.2°	-0.4°	700	470	280	120	120	56
0.2°	+30°	400	270	160	72	72	32
0.5°	-0.4°	160	110	64	28	28	13
0.5°	+30°	75	51	30	13	13	6.0

Type VI Vinyl Micro Prismatic Retroreflective Element Material							
Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE
0.2°	-0.4°	250	170	70	30	35	20
0.2°	+30°	95	64	26	11	13	7.6
0.5°	-0.4°	200	136	56	24	28	18
0.5°	+30°	60	40	17	7.2	8.4	4.8

Type VII Micro Prismatic Retroreflective Element Material							
Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE
0.2°	-0.4°	750	560	280	75	150	34
0.2°	+30°	430	320	160	43	86	20
0.5°	-0.4°	240	180	90	24	48	11
0.5°	+30°	135	100	50	14	27	6.0

Type VIII Micro Prismatic Retroreflective Element Material								
Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE	BROWN
0.2°	-0.4°	700	525	265	70	105	42	21
0.2°	+30°	325	245	120	33	49	20	10
0.5°	-0.4°	250	190	94	25	38	15	7.5
0.5°	+30°	115	86	43	12	17	7	3.5

Type IX Micro Prismatic Retroreflective Element Material							
Obs. Angle	Entrance Angle	WHITE	YELLOW	ORANGE	GREEN	RED	BLUE
0.2°	-0.4°	380	285	145	38	76	17
0.2°	+30°	215	162	82	22	43	10
0.5°	-0.4°	240	180	90	24	48	11
0.5°	+30°	135	100	50	14	27	6.0
1.0	-0.4°	80	60	30	8.0	16	3.6
1.0	+30°	45	34	17	4.5	9.0	2.0

Type X Micro Prismatic Retroreflective Element Material		
Obs. Angle	Entrance Angle	FLUORESCENT ORANGE
0.2°	-0.4°	200
0.2°	+30°	90
0.5°	-0.4°	70
0.5°	+30°	26

The wet performance measurements on unweathered sheeting shall be conducted in accordance with one of the following methods:

1. The standard rainfall test specified in Federal Specification LS 300C and the brightness of the reflective sheeting totally wet by rain shall not be less than 90 percent of the above values.
2. Samples shall be submerged in a tank of clean water (approximately 72°F) for a period of 5 minutes. Reflex-reflective performance of the sheeting shall be viewed in a darkened room by reflected light through the surface of the water or through a transparent plane surface of the tank parallel to the sample surface. Light source shall be such as a hand flashlight held close to the eye. The wet sheeting shall show no apparent loss of reflective performance as compared to dry material.

The sheeting shall conform to the applicable daytime color and luminance factor requirements of ASTM D 4956 when tested instrumentally in accordance with Section 8.4 of that specification; OR, the diffuse day color of the reflective sheeting shall be visually evaluated by comparison with the applicable Highway Color Tolerance Chart. Color comparison shall be made under north daylight or a scientific daylight having a color temperature from 6500 degrees to 7500 degrees Kelvin. Daytime color evaluation shall be illuminated at 45 degrees and viewed at 90 degrees. There shall be no significant color shift when viewed under nighttime (retroreflective) conditions.

The reflective sheeting shall have a pre-coated pressure sensitive adhesive (Class 1) or a heat-activated adhesive (Class 2) either of which will adhere to flat, clean surfaces without necessity of additional adhesive coats on the reflective sheeting or application surface. Chemical activators shall not be used to activate Class 2 adhesive. The pre-coated adhesive shall be protected by an easily removed liner which, when removed, shall not have a staining effect on the reflective sheeting and shall be mildew resistant. The protective liner attached to the adhesive shall be removable by peeling without soaking

in water or other solvents and shall be easily removed after storage for 4 hours at 150ºF under weight of 215-psi. The sheeting with liner removed, conditioned for 24 hours at 72°F and 50 percent relative humidity, shall be sufficiently flexible to show no cracking when bent around a 1.2-inch diameter mandrel with the adhesive side contacting the mandrel. For ease of testing, talcum powder may be spread on the adhesive to prevent sticking to the mandrel. The sheeting surface shall be smooth and flat to facilitate self-cleaning in the rain, regular cleaning, and wet performance, and exhibit 85 degrees glossmeter rating of not less than 50 when tested in accordance with ASTM D 523. The sheeting surface shall be readily processed and compatible with transparent and opaque process colors and show no loss of the color coat with normal handling, cutting, and application. The sheeting shall permit cutting and color processing at temperatures of 60°F to 100°F and 20 to 80 percent RH. The sheeting shall be heat resistant and permit force curing without staining of unapplied sheeting or applied sheeting at temperatures recommended by the manufacturer not to exceed 150°F for unapplied sheeting or 200°F for applied sheeting. The sheeting surface shall be solvent resistant to permit cleaning by wiping with a clean soft cloth dampened with VM&P Naphtha or mineral spirits.

The adhesive shall form a durable bond to smooth, corrosion and weather resistant surfaces and permit the reflective sheeting to adhere securely, 48 hours after application at temperatures of -30°F to 200°F. The adhesive bond shall be sufficient to render the applied sheeting vandal-resistant and prevent its shocking off when subjected to an impact energy of 20 ft. lbs. applied with a hemispherical tipped object 1-inch in diameter at -0°F. The test specimen shall be applied to aluminum backing not less than 0.080-inch thick and having a dimension of not less than 4-inches square. During testing, the specimen shall be supported on a 3-inch diameter ring.

The adhesion test shall conform to ASTM D 4956 with the addition of the temperatures noted above.

The resistance to accelerated weathering shall be as described in ASTM D 4956 except the weathering apparatus and procedure shall be in accordance with ASTM G 154.

The reflective sheeting shall be sufficiently flexible to be cut to shape easily and permit application over, and conform to, moderate shallow embossing characteristic of certain sign borders and symbols. The tensile strength of the sheeting shall be 5 to 20 pounds per square inch width when conditioned for 48 hours in accordance to ASTM D 685 and tested in accordance with ASTM D 828. Following liner removal, the reflective sheeting shall not shrink more than $^{1}/_{32}$-inch in ten minutes nor more than $^{1}/_{8}$-inch in 24 hours in any dimension per 9-inch square at 72°F and 50 percent relative humidity.

The sheeting, when applied according to manufacturer's recommendations to cleaned and etched 0.020-inch x 2-inch x 8-inch aluminum, conditioned (24 hours) and tested at 72°F and 50 percent relative humidity, shall be sufficiently flexible to show no cracking when bent around a $^{3}/_{4}$-inch diameter mandrel.

9-28.12(1) Application

The reflective sheeting shall be applied in the manner specified by the sheeting manufacturer. The applied sign face shall not have bubbles, wrinkles, or foreign material beneath the reflective sheeting.

9-28.12(2) Edge Treatment

All edges and splices of reflective sheeting signs shall be coated with an edge sealer when recommended by the manufacturer of the reflectorized sheeting.

9-28.12(3) Splices and Color Matching

Splicing of reflective sheeting shall not be permitted on signs or panels with dimensions up to and including 48-inches in height or width unless the reflective sheeting specified does not come in this width, then the widest width material shall be used. When sheeting joints are required, they shall be lap-jointed with the top sheet overlapping the bottom sheet by no less than 3/16-inch. The fabricator shall endeavor to use the least number of seams possible with the horizontal lap preferable. Roller applied or reverse screened sheeting may be butt-jointed with joint gap not to exceed 1/32-inch. Color matching of adjacent sheets of reflective sheeting comprising a sign shall be accomplished without a noticeable difference in color. No borders shall be spliced other than the splice of the tangent border to the corner radius.

9-28.13 Demountable Prismatic Reflectorized Message and Borders

The letters, digits, and alphabet accessories shall consist of embossed 0.040-inch thick sheet aluminum frames conforming to ASTM B 209 grade 3003-H14 in which prismatic reflectors are installed to prevent their displacement in handling or service. Letters in which reflectors are assembled by means of tape are unacceptable. The plastic reflectors face shall be colorless and be entirely smooth to present a water repellent and dirt resistant surface. The area indicating the letter shape that is not reflectorized shall be white for maximum daytime contrast with the sign background. All letters shall be free of any imperfections and shall present a high quality appearance. Demountable prismatic border shall be comprised of a minimum length of 2-feet with allowance of one shorter section between each corner radius.

Letters shall be fastened to the sign with aluminum screws or blind rivets conforming to ASTM B 209 grade 2024-T4.

The coefficient of retroreflection of each reflex reflector intended for use in cutout letters, symbols, and accessories shall be equal to or exceed the following minimum values with measurements made with reflectors spinning.

Observation Angle (degrees)	Entrance Angle (degrees)	Coefficient of Retroreflection Candle Power/Square inch/ Foot Candle
0.1	0	14.0
0.1	20	5.6

Failure to meet the specific minimum values shall constitute failure of the reflector being used. Upon failure of more than two of the 50 samples tested, a resample of 100 reflectors shall be tested. Failure of more than four of these samples shall be cause for rejection of the lot.

9-28.14 Sign Support Structures

All sign support structures shall be constructed as shown in the Plans.

9-28.14(1) Timber Sign Posts

At the Contractor's options, timber sign posts and mileposts shall be treated Douglas Fir or treated Hem-Fir meeting the grades specified in Section 9-09.2. Douglas Fir and Hem-Fir posts shall be given a treatment in accordance with Section 9-09.3(1). Preservative retention shall be as shown in Section 9-16.2 for sawn posts.

9-28.14(2) Steel Structures and Posts

Truss chords, struts, and diagonals, end posts, and end post struts and diagonals for sign bridge structures and cantilever sign structures shall conform to either ASTM A 36 or ASTM A 53 Grade B Type E or S. The nominal pipe diameter and the pipe wall thickness shall be as shown in the Plans or Standard Plans. All other structural steel for sign bridge structures and cantilever sign structures shall conform to either ASTM A 36 or ASTM A 992. Truss member connection hardware shall conform to Section 9-06.5(3).

Pipe members for bridge mounted sign brackets shall conform to ASTM A 53 Grade B Type E or S, and shall be Schedule 40 unless otherwise specified. All other structural steel for bridge mounted sign brackets shall conform to either ASTM A 36 or ASTM A 992. U bolts, and associated nuts and washers, shall be stainless steel conforming to Section 9-28.11, and shall be fabricated hot.

Anchor rods for sign bridge and cantilever sign structure foundations shall conform to ASTM F 1554 Grade 105, including Supplemental Requirements S2, S3, and S5. Nuts and washers for sign bridge and cantilever sign structure foundations shall conform to AASHTO M 291 Grade DH and AASHTO M 293, respectively.

Steel sign structures and posts shall be galvanized after fabrication in accordance with AASHTO M 111, unless noted otherwise in the Plans. All bolts, nuts, and washers shall be galvanized after fabrication in accordance with AASHTO M 232. Unless otherwise specified in the Plans or Special Provisions, metal surfaces shall not be painted.

Except as otherwise noted, steel used for sign structures and posts shall have a controlled silicon content of either 0.00 to 0.04 percent or 0.15 to 0.25 percent. If the Plans or Special Provisions specify painting of the galvanized steel surfaces, then the controlled silicon content requirement does not apply for those steel members. Mill test certificates verifying the silicon content of the steel shall be submitted to both the galvanizer and the Engineer prior to beginning galvanizing operations.

Minor fabricating and modifications necessary for galvanizing will be allowed if not detrimental to the end product as determined by the Engineer. If such modifications are contemplated, the Contractor shall submit to the Engineer, for approval, six copies of the proposed modifications, prior to fabrication.

9-28.14(3) Aluminum Structures

Welding of aluminum shall be in accordance with Section 6.9 of the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*, Fourth Edition, 2001.

Aluminum materials shall conform to ASTM B 209 grades as follows: the filler alloy shall be 4043, 5365, or 5556 for welding base metals 6061 or 6063 to 6061, 6063, 356, or A356. Filler alloy for welding base metal 5086 shall be 5356 or 5556.

9-28.15 Vacant

9-29 ILLUMINATION, SIGNAL, ELECTRICAL

9-29.1 Conduit, Innerduct, and Outerduct

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

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

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

Grounding end bushings shall comply with the following:

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

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

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

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

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

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

All types of conduit shall be free from defects, including out of round, foreign inclusions, etc. Conduit shall be uniform in color, density, and physical properties. Conduit shall be straight and the ends shall be cut square to the inside diameter. All conduit shall display the Underwriters Laboratory certification (UL Listed).

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

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

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

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

Expansion, and Deflection Fittings

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

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

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

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

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

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

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

Inner and Outer duct

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

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

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

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

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

Innerduct for Straight Sections of PVC and Rigid Galvanized Steel Conduits

The 4-inch PVC outerduct shall be equipped with four innerducts. The innerducts shall have a minimum outside diameter of $1^1/_4$-inch a minimum inside diameter of $1^1/_5$-inch. Larger diameter innerducts may be provided if the wall thickness and diameter tolerances are met. The tolerance for inside and outside diameters shall be 0.0005-inch. The innerducts shall have a minimum wall thickness of 0.006-inch. Innerduct shall be color coded. The color coding shall be three gray and one white. Alternate color codes are permitted as long as the color codes are contiguous between adjacent junctions boxes. The innerducts shall be factory installed in the outerduct.

Dynamic coefficient of friction of innerducts shall be tested in accordance with Telcordia GR-356-CORE procedure. The coefficient of friction shall be less than 0.30 between medium density polyethylene jacketed fiber optic cable and the prelubricated innerduct. The coefficient of friction shall be less than 0.10 between the $^1/_4$-inch diameter polypropylene rope (suitable for fiber optic cable pulling) and the prelubricated innerduct. Pull rope used for testing (meeting the 0.10 coefficient of friction requirement) shall be the same type as the pull rope used for cable installation. The Contractor shall provide, as part of the conduit submittals, a certificate of compliance with Section 1-06.3 stating that the conduit meets the coefficient of friction requirements detailed above.

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

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

PVC Outerduct

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

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

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

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

Bends for 4-inch PVC Conduit with Innerducts

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

Prefabricated fixed Bends (for Innerducts)

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

Direction changes shall not exceed 90 degree.

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

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

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

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

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

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

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

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

9-29.2 Junction Boxes

Junction boxes shall conform to the requirements set forth in the contract.

9-29.2(1) Standard Junction Box

Standard junction boxes shall be concrete junction boxes conforming to details in the Standard Plans, or approved non-concrete junction boxes.

Concrete junction boxes shall have a minimum compressive strength of 6000 psi when reinforced with a welded wire hoop and 4000 psi when reinforced with welded wire fabric or fiber reinforcement. The frame shall be anchored to the box by welding the wire fabric to the frame or by welding headed studs $^{3}/_{8}$-inch X 3-inches long, as specified in Section 9-06.15, to the frame. The wire fabric shall be attached to the studs and frame with standard tie practices. The box shall contain ten studs located near the centerline of the frame and box wall. The studs shall be placed one anchor in each corner, one at the middle of each width and two equally spaced on each length of the box. The steel frame, lid support, and lid shall be painted with a black paint containing rust inhibiters or painted with a shop applied, inorganic zinc primer in accordance with Section 6-07.3 or hot dip galvanized in accordance with ASTM A 111.

Material for concrete junction boxes shall conform to the following:

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

Non-concrete junction boxes shall be gray in color and shall have an open bottom design with approximately the same inside dimensions as concrete junction boxes. Non-concrete junction box lids shall include a pull slot and shall be secured with two ½-inch stainless steel hex-head bolts factory coated with anti-seize compound and recessed into the cover. The tapped holes for the securing bolts shall extend completely through the box to prevent accumulation of debris. Bolts shall conform to ASTM F 593, stainless steel.

Non-concrete junction boxes shall have a vertical load strength of 15,000 pounds applied uniformly through a 10-inch x 10-inch x 1-inch steel plate centered on the cover. The junction box will be considered to have withstood the test load if:

1. The lid is fully functional.
2. There is no vertical or horizontal displacement of the lid frame.
3. The junction box holds its shape.

When requested, a test report from an independent materials testing facility shall be provided showing compliance with the load test.

9-29.2(2) Vacant

9-29.2(3) Structure Mounted Junction Box

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

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

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

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

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

9-29.2(4) Cover Markings

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

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

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

9-29.3 Conductors, Cable

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

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

1. All current carrying single conductors shall be stranded copper conforming to ASTM B3 and B8. Insulation shall be 600 volt. Except as allowed in item 3, chemically cross-linked polyethylene or EPR Type USE insulation of code thickness is required for all current carrying single conductors in underground electrical systems. Grounding electrode conductor and bonding jumpers shall be bare or insulated stranded copper, 8 AWG minimum or larger as required by the NEC. Equipment grounding conductors shall be insulated, stranded copper with type XHHW, THWN, or USE insulation, non jacketed 8 AWG minimum or larger as required by the NEC. Insulated Grounding Electrode conductors, bonding jumpers and equipment grounding conductors, shall have continuous green color or green color with one or more yellow stripes.
2. Two and three conductor signal control cable shall consist of three No. 14 stranded copper conductors. Each conductor shall have 20-mil polyethylene insulation and a 10-mil PVC jacket. The cable shall be rated at 600 volts minimum. The cable assembly shall be covered with a polyester tape applied with a 10 percent minimum lap. The overall jacket shall be 45-mil PVC.

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

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

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

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

9-29.3(1) Fiber Optic Cable

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

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

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

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

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

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

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

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

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

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

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

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

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

Fibers shall contain no factory splices.

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

9-29.3(1)A Singlemode Fiber Optic Cable

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

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

Typical Core Diameter: 8.3 microns

Cladding Diameter: 125 micron

Core-to-Cladding Offset:< 0.8 microns.

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

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

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

Coating Diameter of 250 microns +/- 15 microns with a minimum coating thickness at any point of not less than 50 microns.

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

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

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

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

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

9-29.4 Messenger Cable, Fittings

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

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

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

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

9-29.5 Vacant

9-29.6 Light and Signal Standards

Light and signal standards shall be in accordance with the details shown in the Plans, as specified in the Special Provisions and as outlined herein, provided that only one type of light or signal standard shall be used throughout the project.

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

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

9-29.6(1) Steel Light and Signal Standards

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

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

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

9-29.6(1)A Vacant

9-29.6(2) Slip Base Hardware

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

Galvanized bolts shall meet standard specification 9-06.5(4).

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

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

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

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

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

9-29.6(4) Welding

Welding of steel structures shall be in accordance with Section 5.15 of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, Fourth Edition-2001.

9-29.6(5) Foundation Hardware

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

Anchor bolts for Type II, III, IV, and V signal standards and luminaire poles shall meet the requirements of ASTM A 449. Nuts shall be heavy hex meeting the requirements of AASHTO M 291, Grade C, D, or DH. Washers shall meet the requirements of AASHTO M 293.

All foundation hardware shall be 100% hot-dipped galvanized in accordance with AASHTO M 111 and AASHTO M 232. Galvanized bolts shall be tested for embrittlement in accordance with ASTM A 143.

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

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

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

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

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

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

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

9-29.8 Vacant

9-29.9 Ballast, Transformers

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

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

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

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

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

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

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

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

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

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

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

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

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

9-29.10 Luminaires

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

A. All luminaires shall be of the IES distribution type and wattage indicated in the contract. Luminaires shall be installed with HPS lamps rated at 24,000 hours, unless otherwise specified in the contract or this specification.

B. Conventional highway luminaires shall provide a full cut-off distribution and a high pressure sodium light source.

C. Horizontal luminaires shall attach to 2-inch pipe tenons on mast arms. Vertical mounted luminaires shall be appropriately sized for their respective pole top tenons.

D. All luminaires shall have their component secured to the luminaire frame with AISI, 300 series chrome-nickel grade stainless steel, zinc dichromate coated steel or ceramic coated steel hardware for corrosion resistant and chemical bonding resistant attachment to the cast aluminum housing or doors. The luminaire slip-fitter bolts shall be either stainless steel, hot-dip galvanized steel, zinc dichromate coated steel, or ceramic coated steel. All internal luminaire assemblies shall be assembled on or fabricated from either stainless steel or galvanized steel. The housing, complete with integral ballast, shall be weathertight. The ballast and lamp housing shall be on the same level.

E. All luminaires shall be mounted level, both transverse and longitudinally, as measured across points specified by the manufacturer. Leveling and orientation shall be accomplished after pole plumbing. Highway and decorative luminaires shall have slip-fitters capable of adjusting through a 5-degree axis for the required leveling procedure.

F. Refractors shall be formed from heat resistant, high impact, molded borosilicate glass. Flat lens shall be formed from heat resistant, high impact borosilicate or tempered glass.

H. High pressure sodium cobra head luminaires shall be capable of accepting a 150, 200, 250, 310, or 400 watt lamp complete with ballast. Metal halide fixtures shall be capable of accepting a 175, 250 or 400 watt lamp complete with ballast. Mercury vapor fixtures shall be capable of accepting a 175, 250, 400 watt lamp complete with ballast. Metal halide fixture shall accept a 175 watt mercury vapor lamp complete with ballast. Each luminaire shall consist of a housing, a reflector, lens, a lamp socket, an integral ballast, a terminal strip and lamp.

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

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

1. A vertical plane at a minimum peak acceleration level of 3.0 g's peak-to-peak sinusoidal loading (same as 1.5 g's peak) with the internal ballast removed, for a minimum of 2 million cycles without failure of any luminaire parts, and
2. A horizontal plane perpendicular to the direction of the mast arm at a minimum peak acceleration level of 1.5 g's peak to peak sinusoidal loading (same as 0.75 g's peak) with the internal ballast installed, for a minimum of 2 million cycles without failure of any luminaire parts.

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

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

Legends shall correspond to the following code:

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

9-29.10(1) Cobra Head Luminaires

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

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

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

9-29.10(2) Decorative Luminaires

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

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

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

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

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

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

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

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

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

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

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

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

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

9-29.10(4) Underdeck and Wall Mount Luminaires

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

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

All lamp sockets shall be positioned to locate the light center of the lamp within $^1/_2$-inch of the light center location for which the luminaire is designed.

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

9-29.10(5) Sign Lighting Luminaires

Sign lighting luminaires shall be either Mercury Vapor or Induction.

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

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

The housing shall encase a reflector, lamp socket, and ballast. It shall have a front entry (the side facing the sign) suitable for $^1/_2$-inch conduit and mounting holes for attaching to a fixture mounting plate. Any additional entries shall have suitable plugs. The sign lighting luminaire shall be supported by a lighting bracket assembly as detailed in the plans. If the sign structure includes a maintenance walkway, the luminaire fixture mounting plate shall be bolted to the walkway grating. Condensation drain holes shall be provided as recommended by the manufacturer.

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

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

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

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

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

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

B. The average to minimum uniformity ratio for a panel as dimensioned above shall not numerically exceed 3:1. Average initial illuminance shall exceed 10 foot candles for a mercury vapor lamp of 175 watts as specified.

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

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

Each fixture shall consist of a housing, a reflector, refractor or lens, lamp socket, lamp, power coupler, a high frequency (HF) generator and a fuse block, door, front entry (the side facing the sign) suitable for $^1/_2$-inch conduit and mounting holes for attaching to a fixture mounting plate. Any additional entries shall have suitable plugs. The sign lighting luminaire shall be supported by a lighting bracket assembly as detailed in the plans. The door shall be hinged to the housing on the side of the fixture away from the sign panel and shall be provided with two captive devices. The door shall be provided with the means to allow the door to be locked in the open position 70 degree to 90 degree from the plane of the door opening. The juncture of the door and housing shall be gasketed to provide a rain tight and dust tight joint.

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

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

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

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

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

Housing

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

Reflector

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

Lamp

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

Power Coupler

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

High Frequency Generator

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

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

High frequency generators shall be designed for continuous operation at ambient air temperatures from -5°F to 80°F without reduction in generator life. High frequency generators shall have a design life of not less than 100,000 hours at130° F.

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

A. High frequency generators shall be capable of being easily replaced. All conductor terminals shall be identified as to the component terminal to which they connect.

B. High frequency generators shall be mounted so as to use the portion of the sign lighting fixture upon which they are mounted as a heat sink.

9-29.11 Control Equipment

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

9-29.11(1) Time Clock Controls

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

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

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

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

9-29.11(2) Photoelectric Controls

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

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

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

9-29.12 Electrical Splice Materials

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

9-29.12(1) Illumination Circuit Splices

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

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

9-29.12(2) Traffic Signal Splice Material

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

9-29.13 Traffic Signal Controllers

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

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

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

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

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

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

The traffic signal control equipment shall conform to the contract specifications and these standard specifications.

All control equipment shall be as specified below:

A. NEMA control and all auxiliary equipment shall conform to current NEMA specifications.

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

C. The 170E/HC-11 controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 170E/HC-11 controller and auxiliary equipment. The 170E shall be compatible with Type 170E controllers and the current revision of the software specified in the contract.

D. 170 ATC controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 170 ATC controller and auxiliary equipment.

E. Type 2070 controller and all auxiliary equipment shall conform to the current California Department of Transportation Specification for Model 2070 and auxiliary equipment.

F. Type 2070 Lite controller and auxiliary equipment shall conform to the current Oregon Department of Transportation Specification for model 2070 Lite controller and auxiliary equipment.

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

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

9-29.13(1) Vacant

9-29.13(2) Flashing Operations

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

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

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

9-29.13(3) Emergency Preemption

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

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

9-29.13(4) Wiring Diagrams

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

9-29.13(5) Vacant

9-29.13(6) Radio Interference Suppressers

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

Ungrounded terminals shall be insulated from each other and shall maintain a surface leakage distance of not less than $^1/_2$-inch between any exposed current conductor and any other metallic parts with an insulation factor of 100-200 megohms dependent on external circuit conditions.

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

9-29.13(7) Traffic-Actuated Controllers

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

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

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

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

Control equipment shall conform to 9-29.13.

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

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

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

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

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

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

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

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

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

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

R cabinets shall include a fully wired 16-position back panel. Solid-state load switches shall conform to NEMA standards except only optically isolated load switches will be allowed. Load switches shall include indicator lights on the input circuits. The controller cabinet shall have all cabinet wiring installed for eight vehicle phases, four pedestrian phases, four emergency pre-empts, four overlaps (OL A, B, C, D).

3. A power panel with:
   a. A control-display breaker sized to provide 125 percent overload protection for all control equipment and signal displays, 30 ampere minimum.
   b. A 20 ampere accessory breaker wired parallel to the control display breaker. The breaker will carry accessory loads, including vent fan, cabinet light, plug receptacle, etc.
   c. A busbar isolated from ground and unfused for the neutral side of power supply.
   d. A radio interference suppresser to the output side of the control display breaker. See Section 9-29.13(6) for other requirements.
   e. A transient voltage protection device connected to the controller power circuit for protection against voltage abnormalities of 1 cycle or less duration. The protector shall be a solid state high energy circuit containing no spark gap, gas tube, or crow bar component. The current rating of the device shall be 15 amps minimum. The device shall provide transient protection between neutral and ground, line and ground, as well as line and neutral. If the protection circuits fail, they shall fail to an open circuit condition. The device shall meet all requirements of UL standard 1449. The suppressed voltage rating shall be 600 volts or less when subjected to an impulse of 6,000 volts, 3,000 amp source impedance, 8.0/20 microsecond waveform as described in UL 1449. In addition, the device shall withstand, without failure or permanent damage, one full cycle at 264 volts RMS. The device shall contain circuitry to prevent self-induced regenerative ringing. There shall be a failure warning indictor light which shall illuminate when the device has failed and is no longer operable.
   f. Cabinet ground busbar independent (150K ohms minimum) of neutral.
4. A police panel located behind the police panel door with a flash automatic switch and a control-display power line on-off switch. See Section 9-29.13(2) for operational requirements.
5. An auxiliary control panel located inside the controller cabinet with a flash-automatic switch and a controller on-off switch. See Section 9-29.13(2) for operational requirements. A three wire 15 ampere plug receptacle with grounding contact and 20 ampere ground fault interrupter shall also be provided on the panel.
6. A conflict monitor conforming to NEMA standards. See Section 9-29.13(2) for operational requirements. The unit shall monitor conflicting signal indications at the field connection terminals. The unit shall be wired in a manner such that the signal will revert to flash if the conflict monitor is removed from service.

   Supplemental loads not to exceed 10 watts per monitored circuit or other means, shall be provided to prevent conflict monitor actuation caused by dimming or lamp burn-out. Supplemental loads shall be installed on the control

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

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

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

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

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

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

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

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

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

A. Flashers, flash transfer relays, conflict monitor, AC isolators, DC isolators, discriminator modules, program modules, modem modules, load switches, breakers, buses, police panel switches, receptacle requirement, vent fan and auxiliary control panel switches shall conform to the requirements noted in the California Department of Transportation document entitled "Traffic Signal Control Equipment Specifications" specified in Section 9-29.13(7).

B. Flashing operation shall conform to Section 9-29.13(2), except the 8-second flash period described in Item 2 of that section will not be required. Emergency preemption shall conform to Section 9-29.13(3).

The requirements for radio interference suppressor, transient voltage protection, terminal blocks, cabinet light (florescent only), cabinet wiring, wiring diagram and equipment labeling are the same as previously noted for the NEMA control assemblies.

C. Input and output terminals shall be installed with a marking strip with field wire numbers noted in the contract embossed on the strip. All cabinet and field conductor shall have a PVC or polyolefin wire marking sleeve installed, matching the input and output terminals above.

D. The input panel terminal blocks TB 2 through TB 9 and associated cable to the input files as described in California Department of Transportation document entitled "Traffic Signal Control Equipment Specifications" dated November 19, 1999 shall be provided in all control assemblies. The alternate raceway specified in Chapter 18 will not be allowed.

E. Supplemental load requirements to prevent conflict monitor actuation on lamp burnout are the same as previously noted for NEMA control assemblies.

F. A "Display Panel", conforming to the requirements previously noted for the NEMA control assemblies shall be provided when noted in the contract.

G. A "Detection Panel" conforming to the requirements previously noted for the NEMA control assemblies shall be provided except the panel shall be a separate unit from the "Display Panel." The panel shall be rack mounted above the controller and shall conform to details in the contract.

H. A "Detector Termination and Interface Panel" shall be provided. When viewing the cabinet from the back, the panel shall be located on the upper left hand side of the cabinet. The panel shall be electrically located between the "Detector Panel" and the C-1 connector. The panel shall utilize insulated terminal blocks and each connector shall be a screw type with post.

I. A print holder rollout drawer shall be provided. The drawer shall be rack mounted below the controller.

J. A "DB-9" socket shall be mounted on the rack facing the front door of the cabinet and shall be easily accessible when the front door is open. The socket shall provide a communication interface between a personal computer and the C-20S connector on the back of the controller. The appropriate cable and C-20 plug connector shall be part of this assembly to provide ease of connection to the controller.

K. A C-2 plug with 6-feet of 22 AWG 4 conductor shielded cable shall be provided in each cabinet. The cable shall be terminated on positions 3, 4, and 6 of the TB terminal block.

L. An "Absence Of Red Programming Assembly" shall be provided. There shall be provided on the back panel of the output file, 16 accessible jumper plug attachment areas, made up of three male pins per position (one set of three, for each conflict monitor channel). Each jumper plug shall be a three position Molex style connector, using crimped wire pins. Two female pins shall be installed in each jumper plug, one attached to each end of a single wire. These pins shall be installed in the connector, one on the center position and one in either outer position of the plug. It shall be possible, by inserting and positioning one of the 16 jumper plugs on the right two pins on the monitor board, to apply 120 VAC into a corresponding channel of the conflict monitor red channels. The connection between the absence of red programming board and the 210 plus conflict monitor shall be accomplished via a 20 pin ribbon cable and the industry standard P-20 connector, that attaches on the front panel of the monitor. It shall be possible, by inserting and positioning one of the 16 jumper plugs on the two left pins on the monitor board, to enable the red monitor on the corresponding channel (phase).There shall be installed on the absence of red programming assembly a red enable disconnect relay, that controls the 120 VAC red enable signal into the 210 plus monitor. During normal operation, the normally closed contacts of this relay shall supply 120 VAC into the red enable input of the monitor. When energized, this red enable signal shall be removed from the input disabling red monitoring. The relay shall be energized by the corresponding Cl pin connection, as required by the local software, to indicate that the assembly is in processor flash.

M. Seven AC – copper neutral bars shall be installed in each 332, 336 controller cabinet, four 4 on the right side and three 3 on the left side. All of the neutral bars shall be secured per the current Caltrans Specification. All neutral bars shall be at the same electrical potential.

9-29.13(7)D NEMA Controller Cabinets

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

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

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

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

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

The above controllers shall be housed in a Models 332, Double 332, 336, 336S, 303 ITS/ATC cabinets, or as specified in the contract. Each door shall be furnished with a construction core lock conforming to Standard Specifications 9-29.13 (7)D 5a, b and c above. A police panel with door, stainless steel hinge pin and lock shall be provided. Two police keys with shafts a minimum of $1^{3}/_{4}$" long shall be provided with each cabinet. Each of these cabinets shall be furnished with auxiliary equipment described in Standard Specification 9-29.13(7)C. Type 334 cabinets for traffic data station controller furnished shall meet current Caltrans 170E specifications, as stated in Section 9-29.13(7) and as follows. Camera control and DMS local control cabinets shall contain the equipment shown in the Plans. The cabinet shall have the same external physical dimensions and appearance of Model 334 cabinets.

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

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

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

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

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

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

   A second transfer relay, Model 430, shall be mounted on the rear of the PDA #3 and wired as shown in the Plans.
4. Police Panel shall contain only one DPDT toggle switch. The switch shall be labeled POLICE CONTROL, ON-OFF.

5. Display Panel

A. General

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

B. Text

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

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

C. LEDs

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

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

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

D. Detector Display Control Switch

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

ON

Detector display LEDs shall operate consistent with their separate switches.

OFF

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

TEST

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

E. Advance Warning Sign Control Switch

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

AUTOMATIC

Sign Relay shall energize upon ground true call from controller.

SIGN OFF

Sign Relay shall de-energize.

SIGN ON

Sign Relay shall energize.

F. Sign Relay

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

G. Detector Input Indicators

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

TEST

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

RUN

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

H. Controller Output Indicators

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

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

I. Connectors

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

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

6. Model 204 Flasher Unit

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

7. Fiber Optic Patch Panel

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

Cabinet Wiring

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

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

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

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

9-29.14 Vacant

9-29.15 Flashing Beacon Control

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

9-29.16 Vehicular Signal Heads

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

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

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

9-29.16(1)A Optical System

The components of the optical system shall comprise:

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

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

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

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

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

9-29.16(1)B Construction

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

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

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

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

9-29.16(1)C Mounting

The signal shall mount to standard $1^1/_2$-inch fittings as a single section, as a multiple section face, or in combination with other signals. The signal section shall be provided with an adjustable connection that permits incremental tilting of at least 0 degree to 10 degree above or below the horizontal while maintaining a common vertical axis through couplers and mounting. Terminal connection shall permit external adjustment about the mounting axis in five degree increments. The signal shall be mountable with ordinary tools and capable of being serviced with no tools.

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

9-29.16(1)D Electrical

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

9-29.16(1)E Photo Controls

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

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

9-29.16(1)F Installation

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

9-29.16(2) Conventional Traffic Signal Heads

9-29.16(2)A Optical Units

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

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

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

1. Light Source: (8-inch Clear Bulb, A21/TS with brass medium base), (67 - 69 Watts), (12-inch clear bulb, P25/TS with brass medium base), (1650 lumens).
2. Voltage: 120 VAC.
3. Rated Initial Lumens at 120 VAC: (8-inch – 550), (12-inch- 1750).

4. Minimum Initial Lumens at 120 VAC: (8-inch – 550), (12-inch –1650).
5. Light Center: (8-inch, $2^{7}/_{16}$-inch), (12-inch, 3-inch).
6. Minimum Life: 8,000 hours.
7. Orientation: the bulb shall be installed with the opening between the filaments up.
6. Operation: The bulb shall operate properly form (-40°F to 170°F)
7. Lens: the lens material shall be prismed glass. The lens shall be secured to the housing with four noncorrosive clips and 4 No. 10 brass screws. The lens shall have a neoprene gasket making the display weather and dust tight.
10. Reflector: The reflector shall be specular aluminum with anodic coating.
11. Reflector Support: The reflector support shall be pivoted to the housing, and shall be designed so that it can be swung out or easily removed without the use of any tools.

9-29.16(2)B Signal Housing

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

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

The body of each signal section shall consist of a one piece corrosion resistant, die cast aluminum alloy. Each section shall have serrated rings top and bottom so when used with proper brackets, each section may be adjustable in respect to an adjoining section, and the hangers may be locked securely to prevent moving. Cast integrally with the housing shall be two hinge lugs and one latch jaw. The top and bottom of the housing shall have an opening to accommodate standard $1^{1}/_{2}$-inch pipe brackets. The sections shall be so designed that when assembled, they interlock with one another forming one continuous weathertight unit. The sections shall be interchangeable and shall be dust and weathertight when assembled with the door and appropriate furnished hardware.

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

Each face shall be protected with a removable visor. The visor shall be tunnel type unless noted otherwise in the contract. Tunnel, cap, and cut away type visors shall be molded using ultraviolet and heat stabilized polycarbonate plastic or be constructed of 0.050-inch corrosion resistant aluminum material throughout as specified in the contract, or as ordered by the Engineer in accordance with Section 1-04.4. Visors shall be flat black in color inside and shall be flat black or dark green on the outside. Visors shall have attaching ears for installation to the housing door. The signal display shall have square doors. End caps shall be made from aluminum or plastic material and shall be installed with fittings to provide a watertight seal. A bead of silicone sealant shall be applied around the perimeter of all top end cap openings prior to installation of the end cap assembly. Plastic end caps shall utilize a threaded stud with seal and wing nut. Plastic end caps utilizing a metal screw that may damage the cap if overtightened will not be allowed. Plastic end caps shall have the same color as the signal housing.

9-29.16(2)C Louvered Visors

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

9-29.16(2)D Back Plates

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

9-29.16(2)E Painting Signal Heads

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

9-29.16(3) Polycarbonate Traffic Signal Heads

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

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

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

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

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

9-29.17 Signal Head Mounting Brackets and Fittings

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

Aluminum

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

Bronze

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

Galvanized Steel

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

Stainless Steel

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

Steel

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

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

Pins for messenger hanger fittings shall be a minimum of $^1/_2$-inch in diameter.

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

9-29.18 Vehicle Detector

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

9-29.18(1) Induction Loop Detectors

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

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

9-29.18(2) Magnetometer Detectors

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

1. Operation. The magnetometer detector unit shall respond to changes in the earth's local magnetic field caused by the passage of a vehicle containing iron or steel over the sensor unit.
2. Environmental Requirements. Satisfactory operation shall be attained over the ambient temperature range from -30°F to 160°F. Operation shall be unaffected by temperature change, water, ice, pavement deterioration, or electromagnetic noise.
3. Modes of Operation. Each detector channel shall be capable of functioning in any of four front-panel selectable modes:
   a. Presence. Time of detection shall be unlimited.
   b. Extended Presence. The detection output shall extend for a timer set value of up to 5 seconds after the detection zone has cleared.
   c. Pulse. A single 30 to 50 millisecond pulse will be generated per detection actuation.
   d. Inhibited Pulse. The detection output will be inhibited for a time set value of up to 5 seconds after the detection zone has cleared.

4. Response Time. Pick up and drop out times shall be consistently within 10 milliseconds.
5. Approach Speed. The unit shall be capable of detecting vehicles traveling from 0 to 80 miles per hour.
6. Sensor Probes. Each channel of the detector unit shall be capable of operating up to three sensing probes.

9-29.19 Pedestrian Push Buttons

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

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

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

9-29.20 Pedestrian Signals

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

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

A. All pedestrian signal heads shall be Neon Grid type or Light Emitting Diode (LED) or LED Walk/Don't Walk module.
B. All pedestrian displays shall comply with ITE publication ST 011B, VTCSH2 or current ITE specification, and the current draft or adopted Caltrans pedestrian LED displays and following requirements:
   (1) All pedestrian signals supplied to any one project shall be from the same manufacturer and type but need not be from the same manufacturer as the vehicle heads.
   (2) Word messages, when specified, shall provide letters a minimum of $4^1/_2$-inches high. Symbol messages, when specified, shall be a minimum of 12-inches high and 7-inches in width.
   (3) Housings shall be green polycarbonate or die-cast aluminum and the aluminum housings shall be painted with two coats of factory applied traffic signal green enamel (Federal Standard 595B). All hinges and latches and interior hardware shall be stainless steel.

9-29.20(1) LED Pedestrian Displays

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

1. Light emitting diode (LED) light sources are required for 12-inch Portland Orange Hand and may be installed for the Lunar White Walking Man. LED displays shall conform to the following:
   a. Wattage (Maximum): 12-inch Portland Orange Hand 15 watts 12-inch Lunar White walking Man 15 watts

b. Voltage: The operating voltages shall be between 85 VAC and 135 VAC.
c. Temperature: Temperature range shall be -35° F to +165° F.
d. LEDs shall be driven at no more than 50% of their rated amperage.
e. 12-inch Portland Orange Hand Circuit Configuration:
   1. LEDs shall be connected to form multiple series circuits, with a minimum of 2 circuits. All series circuits shall be interconnected at intervals forming subcircuits not exceeding 15 LEDs each. These subcircuits shall limit the number of extinguished LEDs to no more than 10% of the total on the display in the event of a single LED failure.
f. 12-inch Lunar White Walking Man 1 Circuit Configuration: LEDs shall be connected to form multiple series circuits, with a minimum of 1 circuits. All series circuits shall be interconnected at intervals forming subcircuits not exceeding 15 LEDs each. These subcircuits shall limit the number of extinguished LEDs to no more than 10% of the total on the display in the event of a single LED failure.
g. Color testing shall be conducted after 30 minutes of continuous operation.
h. LED pedestrian heads shall be supplied with Z crate visors. Z crate visors shall have 21 members at 45 degrees and 20 horizontal members.

9-29.20(2) Neon Grid Type

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

Neon tubing shall be enclosed and shock-mounted inside a rugged plastic module. The unit shall be $1^1/_2$-inches deep. Members shall be constructed of 0.03-inch thick black polycarbonate plastic.

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

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

9-29.21 Flashing Beacon

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

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

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

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

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

9-29.22 Vacant

9-29.23 Vacant

9-29.24 Service Cabinets

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

A. All electrical conductors, buss bars, and conductor terminals shall be copper. Conductor insulation shall be either THW, XHHW, USE, or SIS.

B. If field wiring larger than that which the contactors or breakers will accommodate is required by the contract, a terminal board shall be supplied for use as a splicing block.

C. The minimum size of all other load carrying conductors used within the service cabinets shall be based on the National Electrical Code ampacity tables for not more than three conductors in a raceway or cable.

D. Type B, B Modified, C, D, and E Cabinets shall have ventilation louvers on the lower sides complete with screens. Type D, and E shall also have rain-tight cabinet vents with screens at the top. Cabinet vents shall be gasketed.

E. The Type B modified cabinets shall have one future use double pole circuit breaker. Type D, and E cabinets shall have two future use double pole circuit breakers. The dead front cover shall have cutouts with for all circuits. The receptacle shall be ground fault interrupter equipped.

F. The minimum size of control circuit conductors used in service cabinets shall be 14 AWG stranded copper.

All electrical contactors shall have the loadside terminals toward the front (door side) of the service cabinet.

G. The lighting contactors used shall be specifically rated for tungsten fluorescent and mercury arc lamp loads.

H. All service enclosures shall be fabricated from steel or aluminum. If aluminum, they shall be fabricated from 0.125-inch (minimum) 5052 H 32 ASTM designator or B209 aluminum. If steel, they shall be fabricated from 12 gage (minimum) steel, hot dipped galvanized per AASHTO M 111.

I. All doors and dead front panels installed in service cabinets shall incorporate a hinge placed in a vertical plane. Service doors shall be sealed with closed cell gasket material. The side opposite the hinge shall be secured with quarter turn screws or slide latch. No electrical devices shall be connected to the dead front panel. However, every switch serviced through the dead front panel shall be appropriately identified with its respective circuit designation by means of a screwed or riveted engraved name plate. Such circuit identification shall be submitted for approval together with the appropriate fabrication drawings. Dead front panels shall be intended to provide security only to the switching segment of the service enclosure and shall not cover the electrical contactor portion.

J. A typed index of all circuits shall be mounted on the cabinet door. Each index shall show an entire panel section without folding. Index holders shall have metal returns on the sides and bottom. A schematic of the main panel, any subpanels, circuits, and control circuits shall be provided. The schematic shall be plastic coated and secured in a metal holder.

9-29.24(1) Vacant

9-29.24(2) Electrical Circuit Breakers and Contactors

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

As an alternate to the lighting contactor, the Contractor may furnish a double contact mercury relay. The relay ampere rating shall equal or exceed the rating noted in the contract. The relay shall be normally open and shall be rated for up to 480 VAC resistive. The unit shall have a molded coil enclosure rated for 120 VAC. The contacts shall be evacuated, backfilled with an inert gas and shall be hermetically sealed. The electrode shall be one piece with Teflon wear rings on the internal plunger assembly. All contact terminals and coil connection clamps shall be U.L. approved.

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

9-29.25 Amplifier, Transformer, and Terminal Cabinets

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

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

		Depth	Height	Width
a.	Terminal	8”	16”	12”
b.	Terminal	8”	24”	18”
c.	Transformer Up to 3.0 KVA	12”	18”	18”
	Transformer 23.1 to 12.5 KVA	20”	40”	24”
	Transformer 12.6 to 35 KVA	30”	60”	32”

3. Cabinet doors shall be gasketed with a one-piece closed cell neoprene gasket and shall have a stainless steel piano hinge. The door shall also be provided with a three point latch and a spring loaded construction core lock capable of accepting a Best six pin CX series core. The locking mechanism shall provide a tapered bolt. The contractor shall supply construction cores with two master keys. The keys shall be delivered to the engineer.
4. All seams shall be continuously welded.
5. All cabinets shall provide a door flange.
6. Transformer cabinets shall provide a 9 square inch minimum louvered vent.
7. One spare 12-position terminal block shall be installed in each terminal cabinet and amplifier cabinet.
8. Each Terminal, Amplifier and Transformer cabinet shall have $^{1}/_{8}$-inch drain holes in back corners.

9. Mounting shall be as noted in the contract.
10. Transformer cabinets shall have two separate compartments, one for the transformer and one for the power distribution circuit breakers. Each compartment shall be enclosed with a dead front. Each breaker shall be labeled with the device name.

9-30 WATER DISTRIBUTION MATERIALS

This specification addresses pipe and appurtenances 16-inches in diameter and smaller. Water distribution material incorporated in the work shall be new.

The Contractor shall provide to the Engineer the names of the manufacturer(s) of the water distribution materials proposed for inclusion in the work, which materials shall conform in every respect to these specifications. If so required by the Special Provisions, the Contractor shall provide to the Engineer in addition to the names of the manufacturer(s) of the water distribution materials, a Manufacturer's Certificate of Compliance meeting the provisions of Section 1-06.3, for the materials proposed for inclusion in the work. As used in this specification, the term "lot of material delivered to the work" shall mean a shipment of the water distribution materials as it is delivered to the work.

The Engineer shall have free access to all testing and records pertaining to material to be delivered to the job site. The Engineer may elect to be present at any or all material testing operations.

9-30.1 Pipe

All pipe shall be clearly marked with the manufacturer's name, type, class, and thickness as applicable. Lettering shall be legible and permanent under normal conditions of handling and storage.

9-30.1(1) Ductile Iron Pipe

1. Ductile iron pipe shall be centrifugally cast and meet the requirements of AWWA C151. Ductile iron pipe shall have a cement mortar lining meeting the requirements of AWWA C104. Ductile iron pipe to be joined using bolted flanged joints shall be Standard Thickness Class 53. All other ductile iron pipe shall be Standard Thickness Class 50 or the thickness class as shown in the Plans.
2. Nonrestrained joints shall be rubber gasket, push on type, or mechanical type meeting the requirements of AWWA C111.
3. Restrained joints shall be as specified in Section 9-30.2(6).

9-30.1(2) Polyethylene Encasement

Polyethylene encasement shall be tube-form meeting the requirements of ANSI/AWWA C105 and shall be high-density, cross-laminated polyethylene film, natural or black color.

9-30.1(3) Vacant

9-30.1(4) Steel Pipe

9-30.1(4)A Steel Pipe (6-inches and Over)

Steel pipe 6-inches in diameter and larger shall conform to AWWA C200. The type of protective coating and lining and other supplementary information required by AWWA C200 shall be included in the Special Provisions.

9-30.1(4)B Steel Pipe (4-inches and Under)

Steel pipe 4-inches in diameter and smaller shall be hot-dip galvanized inside and out and meet the requirements of ASTM A 53.

9-30.1(5) Polyvinyl Chloride (PVC)

9-30.1(5)A Polyvinyl Chloride (PVC) Pipe (4-inches and Over)

PVC pipe for water mains shall meet the requirements of ANSI/AWWA C900 or ANSI/AWWA C905. PVC pipe shall have the same outside dimensions as ductile iron pipe. PVC pipe for distribution pipelines shall be a minimum of SDR 18. Pipe shall be listed by Underwriters' Laboratories, Inc.

PVC pipe shall be considered flexible conduit. Joints shall meet the requirements of ASTM D 3139 using a restrained rubber gasket conforming to ASTM F 477. Solvent welded pipe joints are not permitted.

9-30.1(5)B Polyvinyl Chloride (PVC) Pipe (Under 4-inches)

Polyvinyl chloride (PVC) under 4-inches shall meet the requirements of ASTM D 2241. Pipe material shall be PVC 1120, PVC 1220, or PVC 2120, and shall have minimum wall thickness equal or greater than a standard dimension ratio (SDR) of 21. Pipe shall bear the National Sanitation Foundation Seal for use to transport potable water. Pipe shall be considered flexible conduit. Joints shall meet the requirements of ASTM D 3139 using a restrained rubber gasket meeting the requirements of ASTM F 477.

9-30.1(6) Polyethylene (PE) Pressure Pipe (4-inches and Over)

PE pressure pipe for water mains shall meet the requirements of ANIS/AWWA C906. Pipe materials shall be high-density polyethylene PE3408 conforming to a minimum cell class 345464 C, D or E per ASTM D 3350. Pipe diameter shall be either iron pipe size per Table 3 and Table 5 or ANSI/AWWA C906. Pipe pressure class shall be as listed in Table 9 of ANSI/AWWA C906 for DR 9 PE3408 material.

9-30.2 Fittings

Bolts, nuts, and washers used for securing fittings shall be of similar materials. Steel bolts shall meet the requirements of ASTM A 307 or ASTM F 568 for carbon steel or ASTM F 593 or ASTM F 738 for stainless steel. Nuts shall meet the requirements of ASTM A 563 or ASTM A 563 for carbon steel or ASTM F 594 or ASTM F 836 for stainless steel. Iron bolts and nuts shall meet the requirements of ASTM A 536, grade 65-45-12.

9-30.2(1) Ductile Iron Pipe

Fittings for ductile iron pipe shall meet the requirements of AWWA C110 or AWWA C153. Joints shall meet the requirements of AWWA C111. Fittings shall be cement mortar lined, meeting the requirements of AWWA C104. Gaskets for flat faced or raised faced flanges shall be $\frac{1}{8}$-inch thick neoprene having a durometer of 60 plus or minus 5 or $\frac{1}{16}$ cloth inserted. The type, material, and identification mark for bolts and nuts shall be provided.

9-30.2(2) Vacant

9-30.2(3) Vacant

9-30.2(4) Steel Pipe

9-30.2(4)A Steel Pipe (6-inches and Over)

Fittings for steel pipe 6-inches and larger shall be bell and spigot or welded to match the pipe joints. Welded joints shall conform to AWWA C206. Field couplings shall be bolted, sleeve-type for plain-end pipe conforming to AWWA C219. Expansion joints shall be fabricated steel mechanical slip-type conforming to AWWA C221.

When flanges are required, they shall conform to AWWA C207. Linings and coatings for fittings shall be the same as specified for the adjacent pipe.

9-30.2(4)B Steel Pipe (4-inches and Under)

Fittings for steel pipe 4-inches and under shall be malleable iron threaded type with a pressure rating of 150 psi. Dimensions shall meet the requirements of ANSI B16.3. Threading shall meet the requirements of ANSI B2.1. Material shall meet requirements of ASTM A 47M, Grade 32510. Fittings shall be banded and hot-dip galvanized inside and out.

9-30.2(5) Polyvinyl Chloride (PVC) Pipe

9-30.2(5)A Polyvinyl Chloride (PVC) Pipe (4-inches and Over)

Fittings for PVC pipe shall be the same as specified for ductile iron pipe.

9-30.2(5)B Polyvinyl Chloride (PVC) Pipe (Under 4-inches)

Fittings for PVC pipe under 4-inches shall meet the requirements of ASTM D 2466.

9-30.2(6) Restrained Joints

The restraining of ductile iron pipe, fittings, and valves shall be accomplished by the use of either a bolted or boltless system. Any device utilizing round point set screws shall not be permitted.

All couplings installed underground to connect ductile iron or PVC pipe shall be manufactured of ductile iron.

9-30.2(7) Bolted, Sleeve-Type Couplings for Plain End Pipe

Bolted, sleeve-type couplings, reducing or transition couplings, and flanged coupling adapters used to join plain-end pipe shall meet the requirements of AWWA C219. Buried couplings to connect ductile iron, gray cast iron, or PVC pipe shall be ductile iron. Buried couplings for connecting steel pipe to steel pipe shall be steel.

9-30.2(8) Restrained Flexible Couplings

Restrained flexible couplings shall be locking type couplings in accordance with the Plans or Special Provisions. Any couplings that utilize set screws tightened against the outside pipe wall are not acceptable. Coupling shall be epoxy coated.

9-30.2(9) Grooved and Shouldered Joints

Grooved and shouldered joints shall conform to AWWA C606. Rigid or flexible grooved or shouldered joints shall be as specified in the Special Provisions.

9-30.2(10) Polyethylene (PE) Pipe (4-inches and Over)

Fittings for PE pipe shall meet the requirement of ANSI/AWWA C906. Pipe material shall be high-density polyethylene PE3408 conforming to minimum cell class 345464 C, D or E per ASTM D 3350. Pipe diameter shall be either iron pipe size per Table 3 and Table 5 of ANSI/AWWA C906 or ductile iron pipe size per Table 7 and Table 8 of ANSI/AWWA C 906. Pipe pressure class shall be as listed in Table 9 of ANSI/AWWA C 906 for DR 9 PE3408 material.

9-30.2(11) Fabricated Steel Mechanical Slip-Type Expansion Joints

Fabricated steel mechanical slip-type expansion joints shall meet the requirements of ANSI/AWWA C 221. Buried Expansion joints to connect ductile iron or PVC pipe shall be ductile iron. Buried expansion joints for connecting steel pipe to steel pipe shall be steel.

9-30.3 Valves

Valves shall be provided with hand wheels or operating nuts as designated. Where operating nuts are called for, a standard 2-inch operating nut shall be furnished. Valves shall be nonrising stem type, open counterclockwise, and be equipped with an O ring stuffing box.

9-30.3(1) Gate Valves (3-inches to 16-inches)

Gate valves shall meet the requirements of AWWA C509 or AWWA C515. Gate valves 16-inches in size shall be arranged for operation in the horizontal position by enclosed bevel gearing.

Prior to shipping, three certified copies of performance tests, as specified in Section 6 of AWWA C509 or Sections 5 and 6 of AWWA C515, shall be submitted to the Engineer for review.

9-30.3(2) Vacant

9-30.3(3) Butterfly Valves

Butterfly valves shall be rubber seated and shall meet the requirements of AWWA C504, Class 150B. Butterfly valves shall be suitable for direct burial.

Valve operators shall be of the traveling nut or worm gear type, sealed, gasketed, and permanently lubricated for underground service. Valve operators shall be constructed to the standard of the valve manufacturer to withstand all anticipated operating torques and designed to resist submergence in ground water.

The Contractor shall provide an affidavit of compliance stating that the valve furnished fully complies with AWWA C504.

9-30.3(4) Valve Boxes

Valve boxes shall be installed on all buried valves. The box shall be of cast iron, two piece slip type standard design with a base corresponding to the size of the valve. The box shall be coal tar painted by the manufacturer using its standard. The cover shall have the word “WATER” cast in it.

9-30.3(5) Valve Marker Posts

Posts shall have a 4-inch minimum square section and a minimum length of 42-inches, with beveled edges and shall contain at least one No. 3 bar reinforcing steel.

The exposed portion of the marker posts shall be coated with two coats of concrete paint in a color selected by the Contracting Agency.

The size of the valve and the distance in feet and inches to the valve shall be stenciled on the face of the post, using black paint and a stencil which will produce letters 2-inches high.

9-30.3(6) Valve Stem Extensions

Valve stem extensions shall have a 2-inch square operating nut and self-centering rockplate support. Valves with an operating nut more than 4-feet below grade shall have a valve stem extension to raise the operating nut to within 36-inches of the ground surface.

9-30.3(7) Combination Air Release/Air Vacuum Valves

Combination air release/air vacuum valves shall be designed to operate with potable water under pressure to permit discharging a surge of air from an empty line when filling and relieve the vacuum when draining the system. The valves shall also release an accumulation of air when the system is under pressure. This shall be accomplished in a single valve body designed to withstand 300 psi.

The body and cover shall be cast iron conforming to ASTM A 48, Class 30. Floats shall be stainless steel conforming to ASTM A 240 and designed to withstand 1,000 psi. Seats shall be Buna N rubber. Internal parts shall be stainless steel or bronze.

9-30.3(8) Tapping Sleeve and Valve Assembly

Tapping valves shall be furnished with flanged inlet end connections. The outlet ends shall conform in dimensions to the AWWA Standards for hub or mechanical joint connections, except that the outside of the hub shall have a large flange for attaching a drilling machine. The seat opening of the valve must permit a diameter cut no less than ½-inch smaller than the valve size. Valves specifically designed for tapping meeting the requirements of AWWA C500, and valves meeting the requirements of AWWA C509, will be permitted. Tapping valves shall be of the same type as other valves on the project. Tapping sleeves shall be cast iron, ductile iron, stainless steel, epoxy coated steel, or other approved material.

9-30.4 Vacant

9-30.5 Hydrants

Fire hydrants shall conform to AWWA C502 and shall be of standard manufacture and of a pattern approved by the Contracting Agency.

9-30.5(1) End Connections

The end connections shall be mechanical joint or flanged, meeting the requirements of AWWA C110 and C111.

9-30.5(2) Hydrant Dimensions

Hydrant connection pipes shall be 6-inches inside diameter with 6-inch auxiliary gate valves. Barrels shall have a 7-inch minimum inside diameter. Hydrant length, measured from the bottom of the hydrant to the sidewalk ring, shall provide proper cover at each installed location. Valve openings shall be 5¼-inches minimum diameter. Hydrants shall have two 2½-inch hose nozzles and one pumper nozzle to match Contracting Agency's connection requirements.

Nozzles shall be fitted with cast iron threaded caps with operating nuts of the same design and proportions as the hydrant stem nuts. Caps shall be threaded to fit the corresponding nozzles and shall be fitted with suitable neoprene gaskets of positive water tightness under test pressures. The direction of opening shall be counterclockwise and shall be clearly marked on the operating nut or hydrant top. Hydrants shall be with O ring stem seals. The hydrant shall be painted with two coats of paint to match the owner's existing hydrants.

9-30.5(3) Hydrant Extensions

Hydrant extensions shall have a 6¾-inch minimum inside diameter and shall be gray cast iron or ductile iron and shall conform to the AWWA Standards for such castings. The drillings of the connecting flanges on the extensions shall match the drillings of the flanges on the hydrant.

Hydrant extensions shall also include the necessary hydrant operating stem extensions.

9-30.5(4) Hydrant Restraints

Shackle rods shall be ¾-inch diameter with threaded ends, and shall be ASTM A 36 steel. Shackle rods shall be coated with two coats of asphalt varnish. If a restrained joint system is used, it shall meet the requirements of Section 9-30.2(6).

9-30.5(5) Traffic Flange

Hydrants shall be provided with a traffic flange and shall be equipped with breaking devices at the traffic flange which will allow the hydrant barrel to separate at this point with a minimum breakage of hydrant parts in case of damage. There shall also be provided at this point, a safety stem coupling on the operating stem that will shear at the time of impact.

9-30.5(6) Guard Posts

Guard posts for hydrants shall be provided where shown in the Plans. Guard posts shall be reinforced concrete having a compressive strength of 3,500 psi and shall be 6-feet in length by 9-inches in diameter. Reinforcing shall consist of a minimum of five No. 3 deformed steel bars.

9-30.6 Water Service Connections (2-inches and Smaller)

9-30.6(1) Saddles

Saddles shall be ductile iron, bronze, brass, or stainless steel.

Saddles used for ¾-inch and 1-inch services shall be single strap and may be either AWWA tapered thread or female iron pipe thread outlet. Saddles used for 1½-inch and 2-inch services shall be double strap and shall be female iron pipe thread outlet. Saddles used on PVC pipe shall be formed for PVC pipe and have flat, stainless steel straps.

9-30.6(2) Corporation Stops

Corporation stops shall be made of bronze or brass alloy.

Corporation stops for direct tapping shall have AWWA tapered thread inlet and an outlet connections compatible with either copper or polyethylene tubing.

Corporation stops used with ¾-inch and 1-inch outlet saddles shall have either AWWA tapered thread or male iron pipe thread inlets and outlet connections compatible with either copper or polyethylene tubing. Thread patterns for the saddle outlet and corporation stop inlet shall be the same.

Corporation stops used with 1½-inch and 2-inch outlet saddles shall have male iron pipe thread inlets and outlet connections compatible to connecting service pipes or have male iron pipe thread outlets.

9-30.6(3) Service Pipes

9-30.6(3)A Copper Tubing

Copper tubing shall be annealed, seamless, and conform to the requirements of ASTM B 88M, Type K.

9-30.6(3)B Polyethylene Tubing

Polyethylene tubing shall meet the requirements of AWWA C901. Tubing shall be high molecular mass with a 200 psi rating. Tubing used for ¾-inch and 1-inch shall be either SIDR 7 (iron pipe size) or SDR 9 (copper tube size). Tubing used for 1½-inches and 2-inches shall be SDR 9 (copper tube size).

9-30.6(4) Service Fittings

Fittings used for service connections shall be made of bronze or brass alloy.

Fittings used for copper tubing shall be either compressions or flare type.

Fittings used for polyethylene tubing shall be either compression or stab type. Stab type fittings shall utilize an internal grip ring and O ring seal. Stainless steel liners shall be used when utilizing compression fittings on polyethylene tubing.

9-30.6(5) Meter Setters

Meter setters shall be manufactured and tested in accordance with all applicable parts of AWWA C800.

Meter setters shall have an angle meter stop with drilled padlock wing, an angle check valve, measure 12-inches in height, and shall have an inlet and outlet threads compatible with fittings connecting to service pipes.

Meter setters for 5/8-inch by ¾-inch,¾-inch, and 1-inch services shall have meter saddle nuts for installation and removal of the meter.

Meter setters for 1½-inch and 2-inch services shall be equipped with a locking bypass.

9-30.6(6) Bronze Nipples and Fittings

Bronze threaded nipples and fittings shall meet the requirements of ANSI B-16.15, ASA 125 pound class.

9-30.6(7) Meter Boxes

Meter boxes and covers located in the non-traffic areas shall be constructed of either reinforced concrete or high-density polyethylene. High-density polyethylene meter boxes and covers shall have a tensile strength conforming to ASTM D 638. Meter box covers shall include a reading lid.

Meter boxes located in traffic areas shall be constructed of reinforced concrete, cast iron, or ductile iron. Traffic covers shall be constructed of aluminum, steel, cast iron, or ductile iron. Meter boxes and covers shall be designed for H-20 loading.

9-31 ELASTOMERIC BEARING PADS

9-31.1 Requirements

Elastomeric bearing pads shall conform to the requirements of AASHTO M 251. The elastomer shall not contain any form of wax.

All bearing pads shall be individually cast with fully molded edges. Corners and edges of molded pads may be rounded at the option of the Contractor. Radius at corners shall not exceed ⅜-inch, and radius of edges shall not exceed ⅛-inch.

Shims contained in laminated bearing pads shall be mill rolled steel sheets not less than 20 gage in thickness with a minimum cover of elastomer on all edges of:

⅛-inch for pads less than or equal to 3-inches thick.

¼-inch for pads greater than 3-inches and less than or equal to 7-inches thick, and

½-inch for pads greater than 7-inches thick.

Steel shims shall conform to ASTM A 1011, Grade 36, unless otherwise noted.

The shims shall be spaced to divide the pad thickness into equal laminations. The bond between the elastomer and metal shims shall be such that, when a sample is tested for separation, failure shall occur within the elastomer and not between the elastomer and the metal shim.

The shear modulus at 73º F or the durometer hardness of the bearing pads shall be as noted in the contract. If durometer hardness is noted, the following shear modulus shall be applicable for shear modulus testing purposes: 50 durometer - 112 psi, 60 durometer - 165 psi, 70 durometer - 250 psi. Elastomer shall be Grade 3.

Elastomeric bearing pads shall be manufactured with the following tolerances:

Overall vertical dimensions:

Design thickness 1¼-inches or less	-0, +⅛-inch
Design thickness over 1¼-inches	-0, +¼-inch

Overall horizontal dimensions:

36-inches and less	-0, +¼-inch
Over 36-inches	-0, +½-inch

9-32 MAILBOX SUPPORT

9-32.1 Steel Posts

The post shall be 2-inches outside diameter, 14 gage, mechanical tubing, and shall conform to ASTM A 513. Galvanizing shall conform to G 90 coating as defined in ASTM A 653, or an approved equal.

Any damage to galvanized paint surfaces shall be treated with two coats of formula A 9-73, Galvanizing Repair Paint, High Zinc Dust Content as specified in Section 9-08.2

9-32.2 Bracket, Platform, and Anti-Twist Plate

The bracket, platform, and anti-twist plate shall be 16 gage sheet steel, conforming to ASTM A 36.

9-32.3 Vacant

9-32.4 Wood Posts

Wood posts shall meet the requirements of Section 9-28.14(1) or Western Red Cedar.

9-32.5 Fasteners

Unless otherwise specified, bolts and nuts shall be commercial bolt stock, galvanized in accordance with ASTM A 153. Washers, unless otherwise specified, shall be malleable iron, or cut from medium steel or wrought iron plate. Washers and other hardware shall be galvanized in accordance with AASHTO M 111.

9-32.6 Snow Guard

Snow guard shall be fabricated in accordance with ASTM F 1071 for expanded metal bulkhead panel, to the dimensioning shown on the Standard Plan. After fabrication, the snow guard shall be galvanized in accordance with AASHTO M 111.

9-32.7 Type 2 Mailbox Support

Type 2 mailbox supports shall be 2", 14 gage steel tube and shall meet the NCHRP 350 crash test criteria. Type 2 mailbox supports shall be installed in accordance with the manufacturer's recommendations.

9-32.8 Concrete Base

The concrete in the concrete base shall meet or exceed the requirements of Section 6-02.3(2)B.

9-32.9 Steel pipe

The requirements for commercially available, Schedule 40, galvanized steel pipe, elbows, and couplings shall be met for all parts not intended to be bent or welded. Welded and bent parts shall be galvanized after fabrication in accordance with AASHTO M 111.

9-32.10 U-Channel Post

U-channel posts shall meet the requirements of ASTM A 29, weigh a minimum of 3 pounds per linear foot, and shall be galvanized according to AASHTO M 111.

9-33 CONSTRUCTION GEOTEXTILE

9-33.1 Geosynthetic Material Requirements

The term geosynthetic shall be considered to be inclusive of geotextiles, geogrids, and prefabricated drainage mats.

Geotextiles, including geotextiles attached to prefabricated drainage core to form a prefabricated drainage mat, shall consist only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation.

Geogrids shall consist of a regular network of integrally connected polymer tensile elements with an aperture geometry sufficient to permit mechanical interlock with the surrounding backfill. The long chain polymers in the geogrid tensile elements, not including coatings, shall consist of at least 95 percent by mass of the material of polyolefins or polyesters. The material shall be free of defects, cuts, and tears.

Prefabricated drainage core shall consist of a three dimensional polymeric material with a structure that permits flow along the core laterally, and which provides support to the geotextiles attached to it.

The geosynthetic shall conform to the properties as indicated in Tables 1 through 8 in Section 9-33.2, and additional tables as required in the Standard Plans and Special Provisions for each use specified in the Plans. Specifically, the geosynthetic uses included in this section and their associated tables of properties are as follows:

Geotextile Application	Applicable Property Tables
Underground Drainage, Low Survivability, Classes A, B, and C	Tables 1 and 2
Underground Drainage, Moderate Survivability, Classes A, B, and C	Tables 1 and 2
Separation	Table 3
Soil Stabilization	Table 3
Permanent Erosion Control, Moderate Survivability, Classes A, B, and C	Tables 4 and 5
Permanent Erosion Control, High Survivability Classes A, B, and C	Tables 4 and 5
Ditch Lining	Table 4
Temporary Silt Fence	Table 6
Permanent Geosynthetic Retaining Wall	Table 7 and Std. Plans
Temporary Geosynthetic Retaining Wall	Tables 7 and 10
Prefabricated Drainage Mat	Table 8
Table 10 will be included in the Special Provisions.	

Geogrid and geotextile reinforcement in geosynthetic retaining walls shall conform to the properties specified in the Standard Plans for permanent walls, and Table 10 for temporary walls.

For geosynthetic retaining walls that use geogrid reinforcement, the geotextile material placed at the wall face to retain the backfill material as shown in the Plans shall conform to the properties for Construction Geotextile for Underground Drainage, Moderate Survivability, Class A.

Thread used for sewing geotextiles shall consist of high strength polypropylene, polyester, or polyamide. Nylon threads will not be allowed. The thread used to sew permanent erosion control geotextiles, and to sew geotextile seams in exposed faces of temporary or permanent geosynthetic retaining walls, shall also be resistant to ultraviolet radiation. The thread shall be of contrasting color to that of the geotextile itself.

9-33.2 Geosynthetic Properties

9-33.2(1) Geotextile Properties

Table 1: Geotextile for underground drainage strength properties for survivability.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1]	
		Low Survivability Woven/Nonwoven	Moderate Survivability Woven/Nonwoven
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	180 lbs./115 lbs. min.	250 lbs./160 lbs. min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	<50%/>50%	<50%/>50%
Seam Breaking Strength	ASTM D4632[3]	160 lbs./100 lbs. min.	220 lbs./140 lbs. min.
Puncture Resistance	ASTM D4833	67 lbs./40 lbs. min.	80 lbs./50 lbs. min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	67 lbs/40 lbs. min.	80 lbs./50 lbs. min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

Table 2: Geotextile for underground drainage filtration properties.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1]		
		Class A	Class B	Class C
AOS	ASTM D4751	#40 US sieve (0.43 mm) max.	#60 US sieve (0.25 mm) max.	#60 US sieve (0.18 mm) max.
Water Permittivity	ASTM D4491	.5 sec^{-1} min.	.4 sec^{-1} min.	.3 sec^{-1} min.

Table 3: Geotextile for separation or soil stabilization.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1]	
		Separation Woven/ Nonwoven	Soil Stabilization Woven/Nonwoven
AOS	ASTM D4751	#30 US sieve (0.60 mm) max.	#40 US sieve (0.43 mm) max.
Water Permittivity	ASTM D4491	.02 sec^{-1} min.	.10 sec^{-1} min.
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	250 lbs./160 lbs. min.	315 lbs./200 lbs. min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	<50%/>50%	<50%/>50%
Seam Breaking Strength	ASTM D4632[2]	220 lbs./140 lbs. min.	270 lbs./180 lbs. min.
Puncture Resistance	ASTM D4833	80 lbs./50 lbs. min.	112 lbs./79 lbs. min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	80 lbs/50 lbs. min.	112 lbs./79 lbs. min.
Ultraviolet (UV) Radiation stability	ASTM D4355	50% strength retained min., after 500 hrs. in weatherometer	50% strength retained min., after 500 hrs. in weatherometer

Table 4: Geotextile for permanent erosion control and ditch lining.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1] Moderate Survivability Woven/Nonwoven	Permanent Erosion Control High Survivability Woven/Nonwoven	Ditch Lining Woven/Nonwoven
AOS	ASTM D4751	See Table 5	See Table 5	#30 US sieve (0.60 mm) max.
Water Permittivity	ASTM D4491	See Table 5	See Table 5	.02 sec^{-1} min.
Grab Tensile Strength,	ASTM D4632	250 lbs./160 lbs. min.	315 lbs./200 lbs. min.	250 lbs./160 lbs. min. min. in machine and x-machine direction
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	15%-50%/>50%	15%-50%/>50%	<50%/>50%
Seam Breaking Strength	ASTM D4632[2]	220 lbs./140 lbs. min.	270 lbs./180 lbs. min.	220 lbs./140 lbs. min.
Burst Strength	ASTM D3785	400 pse/190 psi min.	500 psi/320 psi min.	
Puncture Resistance	ASTM D4833	80 lbs./50 lbs. min.	112 lbs./79 lbs. min.	80 lbs./50 lbs. min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	80 lbs/50 lbs. min.	112 lbs./79 lbs. min.	80 lbs./50 lbs. min.
Ultraviolet (UV) Radiation stability	ASTM D4355	70% strength retained min., after 500 hrs. In weatherometer	70% strength retained min., after 500 hrs. In weatherometer	70% strength retained min., after 500 hrs. In weatherometer

Table 5: Filtration properties for geotextile for permanent erosion control.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1]		
		Class A	Class B	Class C
AOS	ASTM D4751	#40 US sieve (0.43 mm) max.	#60 US sieve (0.25 mm) max.	#70 US sieve (0.22 mm) max.
Water Permittivity	ASTM D4491	.7 sec^{-1} min.	.4 sec^{-1} min.	.2 sec^{-1} min.

Table 6: Geotextile for temporary silt fence.

Geotextile Property	Test Method[2]	Geotextile Property Requirements[1]	
		Unsupported Between Posts	Supported Between Posts with Wire or Polymeric Mesh
AOS	ASTM D4751	#30 US sieve (0.60 mm) max. for slit film wovens #50 US sieve (0.30 mm) max. for all other geotextile types #100 US sieve (0.15 mm) min.	#30 US sieve (0.60 mm) max. for slit film wovens #50 US sieve (0.30 mm) max. for all other geotextile types #100 US sieve (0.15 mm) min.
Water Permittivity	ASTM D4491	.02 sec^{-1} min.	.02 sec^{-1} min.
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	180 lbs. min. in machine direction, 100 lbs. min. in x-machine direction	100 lbs. min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	30% max. at 180 lbs. or more	
Ultraviolet (UV) Radiation stability	ASTM D4355	70% strength retained min., after 500 hrs. in weatherometer	70% strength retained min., after 500 hrs. in weatherometer

[1]All geotextile properties in Tables 1 through 6 are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in the table).

[2]The test procedures used are essentially in conformance with the most recently approved ASTM geotextile test procedures, except for geotextile sampling and specimen conditioning, which are in accordance with WSDOT Test Methods 914 and 915, respectively. Copies of these test methods are available at the State Materials Laboratory in Tumwater.

[3]With seam located in the center of 8-inch long specimen oriented parallel to grip faces.

9-33.2(2) Geosynthetic Properties For Retaining Walls and Reinforced Slopes

All geotextile properties provided in Table 7 are minimum average roll values. The average test results for any sampled roll in a lot shall meet or exceed the values shown in the table. The test procedures specified in the Table are in conformance with the most recently approved ASTM geotextile test procedures, except for geotextile sampling and specimen conditioning, which are in accordance with WSDOT Test Methods 914 and 915, respectively.

Table 7: Minimum properties required for geotextile reinforcement used in geosynthetic reinforced slopes and retaining walls.

Geotextile Property	Test Method	Geotextile Property Requirements Woven/Nonwoven
Water Permittivity	ASTM D4491	.02 sec.$^{-1}$ min.
AOS	ASTM D4751	#20 US sieve (0.84 mm) max.
Grab Tensile Strength, min. in machine and x-machine direction	ASTM D4632	200 lbs/120 lbs min.
Grab Failure Strain, in machine and x-machine direction	ASTM D4632	< 50% / > 50%
Seam Breaking Strength[1]	ASTM D46322	160 lbs/100 lbs min.
Puncture Resistance	ASTM D4833	63 lbs/50 lbs min.
Tear Strength, min. in machine and x-machine direction	ASTM D4533	63 lbs/50 lbs min.
Ultraviolet (UV) Radiation Stability	ASTM D4355	70% (for polypropylene and polyethylene) and 50% (for polyester) Strength Retained min., after 500 Hr. in weatherometer

[1]Applies only to seams perpendicular to the wall face.

[2]With seam located in the center of 8-inch long specimen oriented parallel to grip faces.

The ultraviolet (UV) radiation stability, ASTM D4355, shall be a minimum of 70% strength retained after 500 hours in the weatherometer for polypropylene and polyethylene geogrids and geotextiles, and 50% strength retained after 500 hours in the weatherometer for polyester geogrids and geotextiles.

9-33.2(3) Prefabricated Drainage Mat

Prefabricated drainage mat shall have a single or double dimpled polymeric core with a geotextile attached and shall meet the following requirements:

Table 8: Minimum properties required for prefabricated drainage mats.

Property	Test Method	Prefabricated Drainage Material/Geotextile Property Requirements
Width		12-inches min.
Thickness	ASTM D 5199	0.4-inches min.
Compressive Strength at Yield	ASTM D 1621	100 psi min.
In Plan Flow Rate	ASTM D 4716	
Gradient = 0.1, Pressure = 5.5 psi		5.0 gal. /min./ft.
Gradient = 1.0, Pressure = 14.5 psi		15.0 gal. /min./ft.
Geotextile - AOS	ASTM D 4751	#60 US Sieve max.
Geotextile - Permittivity	ASTM D 4491	> 0.4 SEC -1
Geotextile - Grab Strength	ASTM D 4632	Nonwoven - 110 lb. min.

Prefabricated drainage mats will be accepted based on the manufacturer's certificate of compliance that the material furnished conforms to these specifications. The Contractor shall submit the manufacturer's certificate of compliance to the Engineer in accordance with Section 1-06.3.

9-33.3 Aggregate Cushion of Permanent Erosion Control Geotextile

Aggregate cushion for permanent erosion control geotextile, Class A shall meet the requirements of Section 9-03.9(2). Aggregate cushion for permanent erosion control geotextile, Class B or C shall meet the requirements of Section 9-03.9(3) and 9-03.9(2).

9-33.4 Geosynthetic Approval and Acceptance

9-33.4(1) Source Approval

The Contractor shall submit to the Engineer the following information regarding each geosynthetic proposed for use:

Manufacturer's name and current address,

Full product name,

Geotextile structure, including fiber/yarn type,

Geosynthetic polymer type(s) (for temporary and permanent geosynthetic retaining walls), and

Proposed geotextile use(s).

If the geosynthetic source has not been previously evaluated, or is not listed in the current WSDOT Qualified Products List (QPL), a sample of each proposed geosynthetic shall be submitted to the State Materials Laboratory in Tumwater for evaluation. After the sample and required information for each geosynthetic type have arrived at the State Materials Laboratory in Tumwater, a maximum of 14 calendar days will be required for this testing. Source approval will be based on conformance to the applicable values from Tables 1 through 8 in Section 9-33.2 and additional tables as specified in the Special Provisions. Source approval shall not be the basis of acceptance of specific lots of material unless the lot sampled can be clearly identified and the number of samples tested and approved meet the requirements of WSDOT Test Method 914.

Geogrid and geotextile products that are qualified for use in permanent geosynthetic retaining walls and reinforced slopes (Classes 1, 2, or both) are listed in the current WSDOT QPL.

For geogrid and geotextile products proposed for use in permanent geosynthetic retaining walls or reinforced slopes that are not listed in the current QPL, the Contractor shall submit test information and the calculations used in the determination of T_{al} performed in accordance with WSDOT Standard Practice T925 to the State Materials Laboratory in Tumwater for evaluation. The Contracting Agency will require up to 30 calendar days after receipt of the information to complete the evaluation.

9-33.4(2) Vacant

9-33.4(3) Acceptance Samples

Samples will be randomly taken by the Engineer at the job site to confirm that the geosynthetic meets the property values specified.

Approval will be based on testing of samples from each lot. A "lot" shall be defined for the purposes of this specification as all geosynthetic rolls within the consignment (i.e., all rolls sent the project site) that were produced by the same manufacturer during a continuous period of production at the same manufacturing plant and have the same product name. After the samples have arrived at the State Materials Laboratory in Tumwater, a maximum of 14 calendar days will be required for this testing.

If the results of the testing show that a geosynthetic lot, as defined, does not meet the properties required for the specified use as indicated in Tables 1 through 8 in Section 9-33.2, and additional tables as specified in the Special Provisions, the roll or rolls which were sampled will be rejected. Geogrids and geotextiles for temporary geosynthetic retaining walls shall meet the requirements of Table 7, and Table 10 in the Special Provisions. Geogrids and geotextiles for permanent geosynthetic retaining wall shall meet the requirements of Table 7, and Table 9 in the Special Provisions, and both geotextile and geogrid acceptance testing shall meet the required ultimate tensile strength Tult as provided in the current QPL for the selected product(s). If the selected product(s) are not listed in the current QPL, the result of the testing for Tult shall be greater than or equal to Tult as determined from the product data submitted and approved by the State Materials Laboratory during source approval.

Two additional rolls for each roll tested which failed from the lot previously tested will then be selected at random by the Engineer for sampling and retesting. If the retesting shows that any of the additional rolls tested do not meet the required properties, the entire lot will be rejected. If the test results from all the rolls retested meet the required properties, the entire lot minus the roll(s) that failed will be accepted. All geosynthetic that has defects, deterioration, or damage, as determined by the Engineer, will also be rejected. All rejected geosynthetic shall be replaced at no additional expense to the Contracting Agency.

9-33.4(4) Acceptance by Certificate of Compliance

When the quantities of geosynthetic proposed for use in each geosynthetic application are less than or equal to the following amounts, acceptance shall be by Manufacturer's Certificate of Compliance:

Application	Geotextile Quantity
Underground Drainage	600 sq. yards
Soil Stabilization and Separation	1,800 sq. yards
Permanent Erosion Control	1,200 sq. yards
Temporary Silt Fence	All quantities
Temp. or Perm. Geosynthetic Retaining Wall	Not required
Prefabricated Drainage Mat	All quantities

The Manufacturer's Certificate of Compliance shall include the following information about each geosynthetic roll to be used:

Manufacturer's name and current address,
Full product name,
Geosynthetic structure, including fiber/yarn type,
Polymer type
(for all temporary and permanent geosynthetic retaining walls only),
Geosynthetic roll number,
Proposed geosynthetic use(s), and
Certified test results.

9-33.4(5) Approval of Seams

If the geotextile seams are to be sewn in the field, the Contractor shall provide a section of sewn seam that can be sampled by the Engineer before the geotextile is installed.

The seam sewn for sampling shall be sewn using the same equipment and procedures as will be used to sew the production seams. If production seams will be sewn in both the machine and cross-machine directions, the Contractor must provide sewn seams for sampling which are oriented in both the machine and cross-machine directions. The seams sewn for sampling must be at least 2 yards in length in each geotextile direction. If the seams are sewn in the factory, the Engineer will obtain samples of the factory seam at random from any of the rolls to be used. The seam assembly description shall be submitted by the Contractor to the Engineer and will be included with the seam sample obtained for testing. This description shall include the seam type, stitch type, sewing thread type(s), and stitch density.

9-34 PAVEMENT MARKING MATERIAL

9-34.1 General

Pavement marking materials in this section consist of paint, plastic, tape or raised pavement markers as described in section 8-22 and 8-23 as listed below:

High VOC Solvent Based Paint
Low VOC Solvent Based Paint
Low VOC Waterborne Paint
Temporary Pavement Marking Paint
Type A – Liquid Hot Applied Thermoplastic
Type B – Pre-formed Fused Thermoplastic
Type C – Cold Applied Pre-formed Tape
Type D – Liquid Cold Applied Methyl Methacrylate
Glass Beads
Temporary Pavement Marking Tape
Temporary Raised Pavement Markings

9-34.2 Paint

Paint shall comply with the specifications for high volatile organic compound (VOC) solvent based paint, low VOC solvent based paint or low VOC waterborne paint.

9-34.2(1) High VOC Solvent Based Paint

High VOC solvent based paint material requirements are as follows:

Abrasion Resistance – ASTM D 968

125 liters minimum of falling sand on a 3 mil dry film thickness.

Accelerated Settling – ASTM D 869, modified as follows:

Paint shall be placed in a motor driven machine that raises and lowers a sample tray providing a shock to the sample which accelerates pigment settling. The samples shall be placed in the machine for one week, 24 hours per day, at a temperature of 77 degrees F. The samples shall show no more than 0.25-inch of clear material over the opaque portion of the paint and there shall be no settling below a rating of eight.

Bleeding over asphalt – ASTM D 969, modified as follows:

The reflectance measurement of the paint over asphalt paper shall be at least 90% of the reflectance measurement of the paint over a taped (non-bleeding) surface.

Color – Yellow

Paint draw-downs shall be prepared in accordance with ASTM D 823. The paint shall match Federal Standard 595a, color number 33538 and the tolerance of color variation shall match that shown in the FHWA "Highway Yellow Color Tolerance Chart (PR Color #1)"

Contrast Ratio at 5 mils wet film thickness – ASTM D 2805

White-92% minimum

Yellow-88% minimum

Daylight Reflectance – WSDOT Test Method 314

White paint shall have a minimum reflectance of 86% with a green filter on a 10 mil wet film thickness

Density – ASTM D 1475, at 70 degrees F

White – 12.00 pounds/gallon minimum

Yellow – 12.10 pounds/gallon minimum

Fineness of Dispersion – ASTM D 1210

2 minimum (Hegman Scale)

Flexibility – ASTM D 522

The paint shall be applied at a wet film thickness of 5 mils to a 3x5-inch tin panel that has been solvent cleaned and lightly buffed with steel wool. With the panel kept in a horizontal position, the paint shall be allowed to dry for 18 hours at 75 +/- 5 degrees F then baked for 3 hours at 212 +/- 4 degrees F. The panel shall be cooled to 75 +/- 5 degrees F for at least 30 minutes, bent over a 0.5-inch mandrel and then examined without magnification. The paint shall show no cracking, flaking or loss of adhesion.

No Track Time – (Dry to No-Pick-Up Time)

The paint, when applied in a line at a rate of 10 mils wet film thickness with 7 pounds of glass beads (Section 9-34.4) per gallon of paint added to the paint surface, shall "dry to no-pick-up" in 35 seconds maximum. The test line shall be applied over a 30 day old (approximate), non-beaded state standard paint line. The test line shall be applied using a striper capable of maintaining the 10 mil wet film thickness specified. The glass beads shall be blown onto the line during paint application. The test shall be conducted on dry pavement when the pavement temperature is between 50 and 100 degrees F and the relative humidity is less than 85%. The "dry to no-pick-up" tests shall be performed by having a standard size sedan or equivalent test vehicle coast across the paint line with no turning or accelerating at a speed of approximately 40 mph no more than 35 seconds after the test line is applied to the pavement. A successful test will be considered one in which at least three out of four line crossings show no visible paint from the line tracked onto the adjacent pavement when viewed standing 50-feet from the point where the test vehicle crossed the line.

Nonvolatile Content – ASTM D 2369

65%-68%

Pigment Specifications

Medium Chrome Yellow (yellow paint) – ASTM D 211 Type III

Titanium Dioxide (white paint) – ASTM D 476 Type II, III, or IV

The inert or filler pigments shall be first quality paint grade products.

Pigment Content – ASTM D 2371

53% maximum

Re-dissolve

A 15 mil wet film thickness of paint shall be applied to a glass panel. The paint shall be air dried for 16 hours at 77 degrees F then baked for 4 hours at 140 degrees F. The panel shall be cooled to room temperature and placed in a quart container that is half filled with the same paint being tested. The container shall be sealed and left undisturbed for 18 hours. After removing the panel from the container, a wooden spatula shall be drawn lightly over the painted surface. The immersed portion of the paint film shall be completely dissolved with no evidence of dried paint remaining on the panel.

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Settling – ASTM D 869

The test shall be run for a period of six months. There shall be no settling below a rating of eight.

Storage Stability

Samples shall show no settling as received by the Materials laboratory and only slight soft settling after the sample has aged undisturbed for one month. No hard caking in the bottom of the container shall be permitted. The paint shall not show evidence of heavy caking or settling which requires mechanical means to return the product to usable condition for a period of one year from the date of manufacture. There shall be no viscosity increase in excess of 10 Krebs Units over the originally reported viscosity after aging in the container for six months, and there shall be no evidence of corrosion of the container or decomposition of the product. Field examination of previously un-opened containers shall not disclose evidence of undissolvable gelatinous vehicle separation, heavy skin formation or corrosion of the container on samples in storage one year or less.

Vehicle Composition

The vehicle may be any combination of natural or synthetic resinous materials, except those that dry by the process of oxidation and/or polymerization (such as alkyd resins which are specifically excluded). All resins used must be permanently capable of re-dissolving in the solvent combination used in the paint.

Viscosity – ASTM D 562

86 Krebs units maximum at 50 degrees F

70-75 Krebs units at 70 degrees F

66 Krebs units minimum at 122 degrees F

9-34.2(2) Low VOC Solvent Based Paint

Low VOC solvent based paint material requirements are as follows:

Bleeding over asphalt – ASTM D 969, modified as follows:

The reflectance measurement of the paint over asphalt paper shall be at least 90% of the reflectance measurement of the paint over a taped (non-bleeding) surface.

Chromium Content – ASTM D 3718

< 50 ppm

Color – Yellow

Paint draw-downs shall be prepared in accordance with ASTM D 823. The paint shall match Federal Standard 595a color number 33538 and the tolerance of color variation shall match that shown in the FHWA "Highway Yellow Color Tolerance Chart (PR Color #1)".

Directional Reflectance – WSDOT Test Method 314

White paint shall have a minimum reflectance of 80%.

Density – ASTM D 1475, at 70 degrees F

11.8 pounds/gallon minimum

Flexibility – ASTM D 522

The paint shall be applied at a wet film thickness of 6 mils to a 3x5-inch panel that has been solvent cleaned and lightly buffed with steel wool. With the panel kept in a horizontal position, the paint shall be allowed to dry for 18 hours at 75 +/- 5 degrees F then baked for 3 hours at 140 +/- 4 degrees F. The panel shall be cooled to 75 +/- 5 degrees F for at least 30 minutes, bent over a 0.25-inch mandrel and then examined without magnification. The paint shall show no cracking, flaking or loss of adhesion.

No Track Time – (Dry to No-Pick-Up Time)

The paint, when applied in a line at a rate of 15 mils wet film thickness with 7 pounds of glass beads (Section 9-34.4) per gallon of paint added to the paint surface shall "dry to no-pick-up" in 90 seconds maximum. The test line shall be applied over a 30 day old (approximate), non-beaded state standard paint line. The test line shall be applied using a striper capable of maintaining the 15 mil wet film thickness specified. The glass beads shall be blown onto the line during paint application. The test shall be conducted on dry pavement when the pavement temperature is between 50 and 100 degrees F and the relative humidity is less than 85%. The "dry to no-pick-up" tests shall be performed by having a standard size sedan or equivalent test vehicle coast across the paint line with no turning or accelerating at a speed of approximately 40 mph no more than 90 seconds after the test line is applied to the pavement. A successful test shall be considered one in which at least three out of four line crossings show no visible paint from the line tracked onto the adjacent pavement when viewed standing 50-feet from the point where the test vehicle crossed the line.

Lead Content – ASTM D 3335

0.06% maximum

Nonvolatile Content – ASTM D 2369

65% minimum

Package Stability – ASTM D 1849

6 rating minimum for all criteria

Pigment Content – ASTM D 2371

53% maximum

Re-dissolve

A 15 mil wet film thickness of paint shall be applied to a glass panel. The paint shall be air dried for 16 hours at 77 degrees F then baked for 4 hours at 140 degrees F. The panel shall be cooled to room temperature and placed in a quart container that is half filled with the same paint being tested. The container shall be sealed and left undisturbed for 18 hours. After removing the panel from the container, a wooden spatula shall be drawn lightly over the painted surface. The immersed portion of the paint film shall be completely dissolved with no evidence of dried paint remaining on the panel.

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Skinning

The paint shall not skin within 48 hours in a 3/4 filled tightly closed container.

Settling Properties during Storage – ASTM D 1309

The sample shall show no more than 0.5-inch of clear material over the opaque portion of the paint and there shall be no settling below a rating of seven.

Titanium Dioxide (Rutile Type II) ASTM D 476

White – 1.0 pounds per gallon minimum. (ASTM D 4563)

Yellow – 0.2 pounds per gallon maximum. (ASTM D 4563)

Viscosity – ASTM D 562

105 Krebs units maximum at 50 degrees F

75-85 Krebs units at 70 degrees F

65 Krebs units minimum at 120 degrees F

Volatile Organic Compound Content – ASTM D 3960

1.25 pounds per gallon maximum

9-34.2(3) Low VOC Waterborne Paint

Low VOC waterborne paint material requirements are as follows:

Binder – ASTM D 3168

The binder shall be 100% acrylic.

Chromium Content – ASTM D 3718

<50 ppm

Color – Yellow

Paint draw-downs shall be prepared in accordance with ASTM D 823. The paint shall match Federal Standard 595a color number 33538 and the tolerance of color variation shall match that shown in the FHWA "Highway Yellow Color Tolerance Chart (PR Color #1)"

Contrast Ratio at 15 mils wet film thickness – ASTM D 2805

White – 98% minimum

Yellow – 96% minimum

Directional Reflectance – WSDOT Test Method 314

White paint shall have a minimum reflectance of 88% on a 15 mil wet film thickness

Fineness of Dispersion – ASTM D 1210

3 minimum (Hegman Scale)

Flash Point – ASTM D 93

100 degrees F minimum

Freeze Thaw – ASTM D 2243

5 cycles minimum

No Track Time – (Dry to No-Pick-Up Time)

The paint, when applied in a line at a rate of 15 mils wet film thickness with 7 pounds of glass beads (Section 9-34.4) per gallon of paint added to the paint surface shall "dry to no-pick-up" in 90 seconds maximum. The test line shall be applied over a 30 day old (approximate), non-beaded state standard paint line. The test line shall be applied using a striper capable of maintaining the 15 mil wet film thickness specified. The glass beads shall be blown onto the line during paint application. The test shall be conducted on dry pavement when the pavement temperature is between 50 and 100 degrees F and the relative humidity is less than 85%. The "dry to no-pick-up" tests shall be performed by having a standard size sedan or equivalent test vehicle coast across the paint line with no turning or accelerating at a speed of approximately 40 mph no more than 90 seconds after the test line is applied to the pavement. A successful test shall be considered one in which at least three out of four line crossings show no visible paint from the line tracked onto the adjacent pavement when viewed standing 50-feet from the point where the test vehicle crossed the line.

Lead Content – ASTM D 3335

0.06% maximum

Nonvolatile Content – ASTM D 2369

60% minimum

Nonvolatile Vehicle – ASTM D 2369, ASTM D 3723

Nonvolatile vehicle is calculated from the Nonvolatile content as determined in ASTM D2369 and the Pigment content as determined in ASTM D 3723.

%Nonvolatile vehicle = 100 – (100 - %Nonvolatile content) - %Pigment

Shall be 36% minimum by weight.

pH – ASTM E 70

9.5 minimum

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Scrub Resistance – ASTM D 2486

500 cycles minimum

Static Heat Stability

A one pint lined container shall be filled with approximately 15 fluid ounces of paint. The container shall be sealed with tape and put in an oven maintained at 135 +/-1 degrees F for seven days. The paint shall be removed from the oven and equilibrated at standard conditions (ASTM D 3924). The paint shall be mixed thoroughly with gentle stirring. The viscosity shall be determined. The paint shall show no increase in viscosity greater than 10 Krebs units over the viscosity at 77 degrees F (see Viscosity below) nor shall the paint show any coagulation, lumps or coarse particles.

Viscosity – ASTM D 562

100 Krebs units maximum at 77 degrees F

Volatile Organic Compound Content – ASTM D 3960

1.25 pounds per gallon maximum

9-34.2(4) Temporary Pavement Marking Paint

Paint used for temporary pavement marking shall conform to the requirements of Section 9-34.2 and shall be applied in one application at a thickness of 15 mils or 107 square feet per gallon.

9-34.3 Plastic

Plastic pavement marking materials shall comply with the specifications for:

Type A – Liquid hot applied thermoplastic

Type B – Pre-formed fused thermoplastic

Type C – Cold applied pre-formed tape

Type D – Liquid cold applied methyl methacrylate

9-34.3(1) Type A – Liquid Hot Applied Thermoplastic

Type A material consists of a mixture of pigment, fillers, resins and glass beads that is applied to the pavement in the molten state by extrusion or by spraying. The material can be applied at a continuously uniform thickness or it can be applied with a profiled pattern. Glass beads, intermixed and top dress, shall conform to the manufacturer's recommendations necessary to meet the retroreflectance requirements. Type A material shall conform to the requirements of AASHTO M 249 and the following:

Resin – The resin shall be alkyd or hydrocarbon.

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Skid Resistance – ASTM E 303

45 BPN units minimum

9-34.3(2) Type B – Pre-formed Fused Thermoplastic

Type B material consists of a mixture of pigment, fillers, resins and glass beads that is factory produced in sheet form. The material is applied by heating the pavement and top heating the material. The material shall contain intermixed glass beads. The material shall conform to AASHTO M 249, with the exception of the relevant differences for the materials being applied in the pre-formed state and the following:

Resin – The resin shall be alkyd or hydrocarbon.

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Skid Resistance – ASTM E 303

45 BPN units minimum

9-34.3(3) Type C – Cold Applied Pre-formed Tape

Type C material consists of plastic pre-formed tape that is applied cold to the pavement. The tape shall be capable of adhering to new and existing hot mix asphalt or cement concrete pavement. If the tape manufacturer recommends the use of a surface primer or adhesive, use a type approved by the pavement marking manufacturer. The tape shall also be capable of being inlaid into fresh hot mix asphalt during the final rolling process. The material is identified by the following designations: Type C-1 tape has a surface pattern with retroreflective elements exposed on the raised areas and faces and intermixed within its body and shall conform to ASTM D 4505, Reflectivity Level I, Class 2 or 3, Skid Resistance Level A. Type C-2 tape has retroreflective elements exposed on its surface and intermixed within its body and shall conform to the requirements of ASTM D 4505, Reflectivity Level II, Class 2 or 3, Skid Resistance Level A, and the following:

Retroreflectance – ASTM D 6359 modified as follows: (units are millicandelas/meter^2/lux)

Reflectivity Level I

White – 500 measured with a 30-meter instrument

Yellow – 300 measured with a 30-meter instrument

Reflectivity Level II

White – 250 measured with a 30-meter instrument

Yellow – 175 measured with a 30-meter instrument

9-34.3(4) Type D – Liquid Cold Applied Methyl Methacrylate

Type D material consists of a two part mixture of methyl methacrylate and a catalyst that is applied cold to the pavement. The material can be applied at a continuously uniform thickness or it can be applied with profiles (bumps). The material is classified by Type designation, depending upon the method of application. Type D-1 material is be applied by hand operated extrusion device, pouring or hand troweling. Type D-2 and D-5 material shall be applied by spraying. Type D-3 and D-4 material shall be applied by machine extrusion. Glass beads, intermixed and top dress, shall conform to the manufacturer's recommendations necessary to meet the retroreflectance requirements. Type D-1, D-2, D-3, and D-4 material shall have intermixed glass beads in the material prior to application. Type D-5 material shall have glass beads injected in to the material at application and a second coating of top dressing beads applied immediately after material application. Type D material shall conform to the following:

Adhesion

Asphalt substrate – substrate failure

Portland Cement Concrete substrate – 200 psi.

Chemical Resistance

The material shall show no effect after seven day immersion in anti-freeze, motor oil, diesel fuel, gasoline, calcium chloride, sodium chloride or transmission fluid.

Composition

Type D-1 – One gallon of methyl methacrylate and 3 fluid ounces of benzoyl peroxide powder.

Type D-2, D-3, D-4, and D-5 – Four parts methyl methacrylate and one part liquid benzoyl peroxide.

Elongation – ASTM D 638

20% minimum

Hardness – ASTM D 2240 (Shore Durometer Type D)

55 minimum after 24 hours

No Track Time – ASTM D 711, modified as follows:

15 minutes at 40 mils.

Retroreflectance – ASTM D 6359

Newly applied pavement markings shall have a minimum initial coefficient of retroreflective luminance of 250 mcd/m²/lux for white and 175 mcd/m²/lux for yellow in accordance with ASTM D 6359 when measured with a 30-meter retroreflectometer. WSDOT will measure retroreflectivity for compliance with a Delta LTL-X retroreflectometer.

Skid Resistance – ASTM E 303

45 BPN units minimum

Tensile Strength – ASTM D 638

125 psi minimum at break

Viscosity – ASTM D 2196 Method B, LV Model at 50 rpm.

Type D-1 – 11,000 to 15,000 cps, spindle #7

Type D-2 – 26,000 to 28,000 cps, spindle #7

Type D-3 – 17,000 to 21,000 cps, spindle #7

Type D-4 – 8,000 to 10,000 cps, spindle # 4

Type D-5 White – 5,000 to 8,000 cps, spindle #4

Type D-5 Yellow – 7,000 to 11,000 cps, spindle #4

Ultraviolet Light

No effect

9-34.4 Glass Beads

Glass beads for paint shall conform AASHTO M 247-81, Type 1. All glass beads shall have a moisture resistant coating. Glass beads for high VOC and low VOC solvent based paint shall have a silane coating to enhance adherence with solvent based paint. Glass beads for waterborne paint shall have a dual coating of silicone and silane that provides both anti-wetting and adherence properties.

9-34.5 Temporary Pavement Marking Tape

Temporary pavement marking tape shall be pressure sensitive, reflective type, conforming to ASTM D 4592, designed for application on asphalt or concrete pavement. Biodegradable tape with paper backing shall not be allowed. Surface preparation and application shall be in conformance with all the manufacturer's recommendations. Pavement marking masking tape shall conform to ASTM D 4592 Type 1 (removable), except that material shall be black, non-retroreflective and non-glaring.

9-34.6 Temporary Raised Pavement Markers

Temporary flexible raised pavement markers shall consist of an L-shaped body with retroreflective tape on the top of one face for one-way traffic and reflective tape on the top of both faces for two-way traffic. The marker body shall be made from 0.060-inch minimum thick polyurethane. The top of the vertical leg shall be between 1.75 and 2.0-inches high and shall be approximately 4-inches wide. The base width shall be approximately 1.125-inches wide. The base shall have a pressure sensitive adhesive material, a minimum of 0.125-inch thick with release paper. The reflective tape shall be a minimum of 0.25-inch high by 4.0-inches wide. The reflective tape shall have a minimum reflectance of 3.5 candlepower per foot-candle for white and 2.5 candlepower per foot-candle for yellow measured at 0.2° observation angle and 0° entrance angle. When temporary flexible raised pavement markers are used for bituminous surface treatment operations, the markers shall be supplied with a protective cover made of clear polyvinyl chloride. The cover shall be removed after spraying asphaltic material.

Temporary raised pavement markers other than temporary flexible raised pavement markers shall conform to the requirements of Section 8-09.2.

9-34.7 Field Testing

Field testing is required for all pavement marking materials. The material shall be applied in the field by the manufacturer and shall be monitored to determine durability and appearance characteristics. At the Department's discretion, field performance data gained from independent testing may be submitted in lieu of field testing. Acceptance of independent testing shall be the prerogative of the State Material Laboratory.

9-35 TEMPORARY TRAFFIC CONTROL MATERIALS

9-35.0 General Requirements

Temporary traffic control materials in this section consist of various traffic communication, channelization and protection items described in Section 1-10 and listed below:

Stop/Slow Paddles
Construction Signs
Wood Sign Posts
Sequential Arrow Signs
Portable Changeable Message Signs
Barricades
Traffic Safety Drums
Barrier Drums
Traffic Cones
Tubular Markers
Warning Lights and Flashers
Truck-Mounted Attenuator

The basis for acceptance of temporary traffic control devices and materials shall be visual inspection by the Engineer's representative. No sampling or testing will be done except that deemed necessary to support the visual inspection. Requests for Approval of Material and Qualified Products List submittals are not required. Certification for crashworthiness according to NCHRP 350 will be required as described in Section 1-10.2(3).

"MUTCD," as used in this section, shall refer to the latest WSDOT adopted edition of the *Manual on Uniform Traffic Control Devices for Streets and Highways*. In the event of conflicts between the MUTCD and the contract provisions, then the provisions shall govern.

9-35.1 Stop/Slow Paddles

Paddles shall conform to the requirements of the MUTCD, except that the minimum width shall be 24-inches.

9-35.2 Construction Signs

Construction signs shall conform to the requirements of the MUTCD and shall meet the requirements of NCHRP Report 350 for Category 2 devices. Except as noted below, any sign/sign stand combination that satisfies these requirements will be acceptable.

Where aluminum sheeting is used to fabricate signs, it shall have a minimum thickness of 0.080-inches and a maximum thickness of 0.125-inches.

All orange background signs shall be fabricated with Type X reflective sheeting. All post-mounted signs with Type X sheeting shall use a nylon washer between the twist fasteners (screw heads, bolts or nuts) and the reflective sheeting.

Any fabric sign which otherwise meets the requirements of this section and was purchased prior to July 1, 2004, may be utilized until December 31, 2007. If a fabric sign is used, it shall have been fabricated with Type VI reflective sheeting.

9-35.3 Wood Sign Posts

Post sizes for construction signs shall be as follows:

One Post Installation

Post Size	Min. Sign Sq. Ft.	Max. Sign Sq. Ft.
4x4	-	16.0
4x6	17.0	20.0
6x6	21.0	25.0
6x8	26.0	31.0

Two Post Installation

(For signs 5-feet or greater in width)

Post Size	Min. Sign Sq. Ft.	Max. Sign Sq. Ft.
4x4	-	16.0
4x6	17.0	36.0
6x6	37.0	46.0
6x8	47.0	75.0 *

* The Engineer shall determine post size for signs greater than 75 square feet.

Sign posts shall conform to the grades and usage listed below. Grades shall be determined by the current standards of the West Coast Lumber Inspection Bureau (WCLIB) or the Western Wood Products Association (WWPA).

4 x 4	Construction grade (Light Framing, Section 122-b WCLIB) or (Section 40.11 WWPA)
4 x 6	No. 1 and better, grade (Structural Joists and Planks, Section 123-b WCLIB) or (Section 62.11 WWPA)
6 x 6, 6 x 8, 8 x 10	No. 1 and better, grade (Posts and Timbers, Section 131-b WCLIB) or (Section 80.11 WWPA)
6 x 10, 6 x 12	No. 1 and better, grade (Beams and Stringers, Section 130-b WCLIB) or (Section 70.11 WWPA)

9-35.4 Sequential Arrow Signs

Sequential Arrow Signs shall meet the requirements of the MUTCD supplemented with the following:

Sequential arrow signs furnished for stationary lane closures on this project shall be Type C.

The color of the light emitted shall be yellow.

The dimming feature shall be automatic, reacting to changes in light without a requirement for manual adjustment.

9-35.5 Portable Changeable Message Signs

Portable Changeable Message Signs (PCMS) shall meet the requirements of the MUTCD and the following:

The PCMS shall employ one of the following technologies:

1. Fiber optic/shutter
2. Light emitting diode
3. Light emitting diode/shutter
4. Flip disk

Regardless of the technology, the PCMS shall meet the following general requirements:

1. Be light emitting and must not rely solely on reflected light. The emitted light shall be generated using fiber optic or LED technology.
2. Have a display consisting of individually controlled pixels no larger than $2^1/_2$-inch by $2\ ^1/_2$-inch. If the display is composed of individual character modules, the space between modules must be minimized so alphanumeric characters of any size specified below can be displayed at any location within the matrix.
3. When activated, the pixels shall display a yellow or orange image. When not activated, the pixels shall display a flat black image that matches the background of the sign face.
4. Be capable of displaying alphanumeric characters that are a minimum of 18-inches in height. The width of alphanumeric characters shall be appropriate for the font. The PCMS shall be capable of displaying three lines of eight characters per line with a minimum of one pixel separation between each line.
5. The PCMS message, using 18-inch characters, shall be legible by a person with 20/20 corrected vision from a distance of not less than 800-feet centered on an axis perpendicular to the sign face.
6. The sign display shall be covered by a stable, impact resistant polycarbonate face. The sign face shall be non-glare from all angles and shall not degrade due to exposure to ultraviolet light.
7. Be capable of simultaneously activating all pixels for the purpose of pixel diagnostics. Any sign that employs flip disk or shutter technology shall be programmable to activate the disks/shutters once a day to clean the electrical components. This feature shall not occur when the sign is displaying an active message.
8. The light source shall be energized only when the sign is displaying an active message.

The PCMS panels and related equipment shall be permanently mounted on a trailer with all controls and power generating equipment.

The PCMS shall be operated by a controller that provides the following functions:

1. Select any preprogrammed message by entering a code.
2. Sequence the display of at least five messages.
3. Blank the sign.
4. Program a new message, which may include animated arrows and chevrons.
5. Mirror the message currently being displayed or programmed.

9-35.6 Barricades

Barricades shall conform to the requirements of the MUTCD supplemented by the further requirements of the Standard Plans.

9-35.7 Traffic Safety Drums

Traffic safety drums shall conform to the requirements of the MUTCD and shall have the following additional physical characteristics:

Material	Fabricated from low-density polyethylene that meets the requirements of ASTM D 4976 and is UV stabilized.
Overall Width	18-inch minimum in the direction(s) of traffic flow.
Shape	Rectangular, hexagonal, circular, or flat-sided semi-circular.
Color	The base color of the drum shall be fade resistant safety orange.

The traffic safety drums shall be designed to accommodate at least one portable light unit. The method of attachment shall ensure that the light does not separate from the drum upon impact.

Drums and light units shall meet the crashworthiness requirements of NCHRP 350 as described in Section 1-10.2(3).

When recommended by the manufacturer, drums shall be treated to ensure proper adhesion of the reflective sheeting.

9-35.8 Barrier Drums

Barrier drums shall be small traffic safety drums, manufactured specifically for traffic control purposes to straddle a concrete barrier and shall be fabricated from low-density polyethylene that meets the requirements of ASTM D 4976 and is UV stabilized.

The barrier drums shall meet the following general specifications:

Total height	22 in., ± 1 in.
Cross-section	hollow oval 10 in. X 14 in., ± 1 in.
Formed support legs length	13 in., ± 1 in.
Space between legs (taper to fit conc. barrier)	$6^{1}/_{4}$ in. min.
Weight	33 lb. ± 4 lb. with legs filled with sand.
Color	Fade resistant safety orange.

Barrier drums shall have three 4-inch reflective white stripes, (one complete and two partial). Stripes shall be fabricated from Type III or Type IV reflective sheeting.

When recommended by the manufacturer, barrier drums shall be treated to ensure proper adhesion of the reflective sheeting.

9-35.9 Traffic Cones

Cones shall conform to the requirements of the MUTCD, except that the minimum height shall be 28-inches.

9-35.10 Tubular Markers

Tubular markers shall conform to the requirements of the MUTCD, except that the minimum height shall be 28-inches.

Pavement-mounted tubular markers shall consist of a surface-mounted assembly that uses a separate base with a detachable tubular marker held in place by means of a locking device.

9-35.11 Warning Lights and Flashers

Warning lights and flashers shall conform to the requirements of the MUTCD.

9-35.12 Truck-Mounted Attenuator

The Truck-Mounted Attenuator (TMA) shall be selected from the approved units listed on the Qualified Products List. The TMA shall be mounted on a vehicle with a minimum weight of 15,000 pounds and a maximum weight in accordance with the manufacturer's recommendations. Ballast used to obtain the minimum weight requirement, or any other object that is placed on the vehicle shall be securely anchored such that it will be retained on the vehicle during an impact. The Contractor shall provide certification that the unit complies with NCHRP 230 or 350 requirements. Units fabricated after 1998 must comply with NCHRP 350 requirements.

The TMA shall have an adjustable height so that it can be placed at the correct elevation during usage and to a safe height for transporting. If needed, the Contractor shall install additional lights to provide fully visible brake lights at all times.

The TMA unit shall have a chevron pattern on the rear of the unit. The standard chevron pattern shall consist of 4-inch yellow stripes, alternating non-reflective black and reflective yellow sheeting, slanted at 45 degrees in an inverted "V" with the "V" at the center of the unit.