

SECTION 900 – MATERIALS DETAILS

SECTION 901 – HYDRAULIC CEMENT AND POZZOLANS

901.01 Hydraulic Cement.

(a) General. At the time cement is incorporated into the work, it shall meet the quality requirements of these specifications.

Cement which has been in storage may be tested prior to use, and if tests show that it does not meet the requirements specified it will be rejected.

A means for storing and protecting the cement against dampness shall be provided. Cement which has become partially set or which contains lumps or caked cement will be rejected. Cement salvaged from discarded or used sacks shall not be used.

Different kinds or brands of cement, or cement of the same brand from different mills, even if tested and approved, shall not be mixed during use unless permitted, and then only as directed. They shall not be used alternately in any one pour for any structure, unless otherwise permitted.

(b) Portland Cement. Portland cement shall conform to the requirements of the following cited specifications except as noted.

1. Requirements.

Cement	Specifications
Air-Entraining Portland Blast-Furnace Slag Cement.....	AASHTO M 240, Type ISA
Air-Entraining Portland Cement.....	AASHTO M 85, Type IA or IIIA
Air-Entraining Portland-Pozzolan Cement	AASHTO M 240, Type IP-A
Portland Blast-Furnace Slag Cement.....	AASHTO M 240, Type IS
Portland Cement.....	AASHTO M 85, Type I, II or III
Portland-Pozzolan Cement.....	AASHTO M 240, Type IP

The exceptions to AASHTO M 240 are as follows:

- a. The amount of pozzolan shall be limited to 20% " 5% by weight of the portland-pozzolan cement for the types IP and IP-A.

- b. The pozzolan in the portland-pozzolan cements, types IP and IP-A, shall be in accordance with ASTM C 618, class C or class F with the loss on ignition of the pozzolan limited to a maximum of 3%.
- c. The pozzolan in the portland-pozzolan cements, types IP and IP-A, shall be interground with the portland cement clinker.

50 **2. Acceptance Criteria.** Portland cements and blended cements will be accepted based upon the manufacturer's or manufacturer/distributor's documented ability to consistently furnish these materials in accordance with the applicable AASHTO requirements.

60 **a. General Requirements.** Cements shall comply with the applicable requirements of 901 and will be accepted by certification from qualified manufacturers or manufacturer/distributor. The manufacturer is defined as the plant producing the cement. A manufacturer or manufacturer/distributor shall become qualified by establishing a history of satisfactory quality control of cement produced as evidenced by results of tests performed by a testing laboratory which is regularly inspected by the Cement and Concrete Reference Laboratory of the National Institute of Standards and Technology. Proof of such inspection shall be furnished upon request. All certifications shall be prepared by the manufacturer or distributor in accordance with the applicable requirements of 916. If a manufacturer or distributor elects to supply portland cement with a high sulfur trioxide content in accordance with footnote B from Table 1 in AASHTO M 85, it shall supply all of the required supporting data to the Materials and Tests Division prior to supplying such cement. A list of qualified manufacturers and manufacturer/distributors will be maintained by the Department.

70 The manufacturer or manufacturer/distributor shall conduct sufficient tests to ensure that adequate quality control is maintained and that cement furnished is in accordance with the specification requirements. Documentation pertaining to cement shipped on certification shall be maintained for a period of at least three years and shall be provided when requested.

80 Random samples of cement will be obtained at the concrete plant. If the sample is not in accordance with the specification requirements, an investigation will be conducted. A copy of the findings and conclusions resulting from the investigation will be furnished to the Contractor. Unless the investigation finds the Department is responsible for the failure to comply, the cost of the investigation plus any required corrective action will be assessed to the Contractor.

b. Requirements for Domestic Source Qualification. Cement manufacturers requesting to be qualified to supply cement shall provide the following:

- (1) For the initial qualification, the manufacturer shall provide to the Materials and Tests Division an outline of their quality control procedure including the location and type of samples taken, and a monthly summary of mill test data for the previous years production. A current Material Safety Data Sheet shall be submitted as an integral part of the initial qualification package.
- (2) To maintain qualification, a monthly average of mill test data shall be submitted to the Materials and Tests Division. If a specific type of cement is not manufactured in a given month, the monthly submittal shall state "No type _____ cement was manufactured during the month of _____ 19____".

c. Requirements for Foreign Source Qualification. Foreign cement manufacturers or their domestic distributors requesting to be qualified to supply cement shall provide the following:

- (1) For the initial qualifications, the manufacturer and distributor shall provide to the Materials and Tests Division an outline of their quality control procedures including the location and type of samples taken, and a summary of complete test results from the proposed cement source. A current Material Safety Data Sheet shall be submitted as an integral part of the initial qualification package. The quality control procedure must explain the linkage between the cement being furnished and the manufacturer's/distributor's quality control data, relative to ship-loads, barge-loads, railroad car-loads, etc.
- (2) Once the initial qualifications have been met, the manufacturer or distributor shall be required to furnish the cement test results for each shipment prior to Department cement usage for the first five cement shipments, which are intended for Department use. The test results for all five of these cement shipments must fully comply with the required material specifications. If not, this requirement will be continued for subsequent cement shipments until five consecutive cement shipment test results fully comply with the required material specifications, or Department source approval is withdrawn due to the inability to consistently supply satisfactory cement.

130 (3) To maintain qualification after compliance with the previous requirements, a monthly submission of all cement shipment test results for cement which is intended for Department usage shall be submitted to the Materials and Tests Division. If no cement shipments are received during a given month, the monthly submittal shall state "No cement was received during the month of _____, 19____."

d. Certification. Only qualified manufacturers and manufacturer/distributors as identified by the Department's list of qualified manufacturers and manufacturer/distributors may furnish cement on certification.

140 A sample certification form addressing all of the required information is included in ITM 804. Alternate procedures and forms will be considered when requested, and will be approved if there is a positive link between the cement furnished and the manufacturer's quality control data.

(c) Masonry Cement. Masonry cement shall be in accordance with ASTM C 91, except the air content test and the water retention test may be waived.

901.02 Fly Ash Used as a Pozzolan.

150 **(a) General.** Fly ash is the finely divided residue that results from the combustion of ground or powdered coal. In general, class F fly ash is produced from burning anthracite or bituminous coal and class C fly ash is produced from burning lignite or subbituminous coal.

160 Fly ash will be accepted from one of the sources on the Department's list of approved fly ash and ground granulated blast furnace slag sources. Fly ash from different sources or different types of fly ash shall not be mixed or used alternately in the same construction unless authorized in writing. Fly ash will be subject to random assurance sampling and testing by the Department. Failure of these random samples to meet the specified requirements will be cause for suspension of the fly ash source approval.

(b) Acceptance Criteria. Acceptance is based upon the supplier's documented ability to consistently furnish material in accordance with the specified requirements.

1. Requirements. The fly ash shall be in accordance with AASHTO M 295 for class C or class F, with the following exceptions:

170	Loss on Ignition (LOI), Maximum %.....	3
	Autoclave Expansion or Contraction, Maximum %	0.5
	Fineness: Amount retained when wet-sieved on 45 Fm sieve, (No. 325) Maximum %.....	30

On days when fly ash is being accumulated for use as a pozzolan, the supplier shall obtain a minimum of one sample per day and furnish test results for moisture content, loss on ignition, and 45 :m (No. 325) sieve residue for each sample.

180 For each 1800 Mg (2,000 tons) produced, a complete AASHTO M 295 analysis shall be performed on a sample composited randomly from the daily samples. The method of randomization shall be subject to approval by the Department.

2. Test and Calibration Procedure. The testing procedures followed shall be in accordance with ASTM C 311 or other methods approved in writing by the Department.

The minimum frequency for calibration of test equipment is:

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- a. The 45 Fm (No. 325) sieve shall be calibrated every 100 determinations or every six months, whichever comes first.
 - b. The muffle furnace used for LOI determinations shall have a newly installed thermocouple every six months.
 - c. The analytical balances and scales shall be calibrated each year.
 - d. The concrete compression machine shall be calibrated annually.
 - e. The Blaine apparatus shall be calibrated annually.
 - 200 f. All instrumentation used for rapid chemical analysis shall comply with applicable requirements of ASTM C 114 using NIST Fly Ash reference materials.

3. Documentation. Fly ash suppliers requesting approval shall supply the following:

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- a. For the initial approval, a current Materials Safety Data Sheet and a summary of results for all specified tests for six consecutive months shall be submitted. No test results shall be more than one year old at the time of request.

- b. To maintain approval, a summary of results for all specified tests shall be submitted monthly. The results of the daily tests shall be available by telephone during normal working hours.
- c. The fly ash suppliers shall furnish a quality control program which ensures the Department of a continuous supply of fly ash complying with the requirements. This program will be reviewed to determine its adequacy.

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d. Certification:

- (1) For Source Approval, the supplier shall furnish a certification indicating the class of fly ash, the name, location, and unit of the generating plant. It shall state that all fly ash shipped for use on Department projects will be produced under appropriate quality control and shall be in accordance with the specified requirements. It shall further indicate that the power company will participate in appropriate inspection and assurance testing. A sample certification form is set out in ITM 804.

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- (2) For certification of test reports, the test results generated in accordance with 901.02(b)1 shall be summarized and submitted monthly. The reports shall state the name and location of the testing facility, and shall be signed by the chemist or technical manager. This certification shall also identify the concrete plants receiving fly ash represented by these results.

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901.03 Ground Granulated Blast Furnace Slag Used as a Pozzolan.

(a) General. Blast furnace slag shall consist of the nonmetallic product, consisting essentially of silicates and aluminosilicates of calcium and other bases, that is developed in a molten condition simultaneously with iron in a blast furnace. A glassy granular material is formed when molten blast-furnace slag is rapidly chilled by immersion in water. This material is then ground to cement fineness, producing ground granulated blast furnace slag.

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Ground granulated blast furnace slag will be accepted from one of the sources on the Department's list of approved fly ash and ground granulated blast furnace slag sources. Ground granulated blast furnace slag from different sources or different grades of ground granulated blast furnace slag shall not be mixed or used alternately in the same construction unless approved in writing. Ground granulated blast furnace slag will be subject to random assurance sampling and testing by the Department. Failure of these random samples to be in accordance with the specified requirements will be cause for suspension of ground granulated blast furnace slag source approval.

(b) Acceptance Criteria. Ground granulated blast furnace slag will be accepted based on the manufacturer's or manufacturer/distributor's documented ability to consistently furnish these materials in accordance with the applicable ASTM and AASHTO requirements.

1. Requirements. The ground granulated blast furnace slag shall be in accordance with ASTM C 989 for grade 100 or 120.

For each 1800 Mg (2,000 tons) produced, a complete ASTM C 989 analysis shall be performed on a sample composited randomly from the daily samples. The method of randomization shall be subject to approval by the Department.

2. Test and Calibration Procedure. The testing procedures followed shall be in accordance with ASTM C 989 or other methods approved in writing by the Department.

The minimum frequency for calibration of test equipment is:

- a. The 45 :m (No. 325) sieve shall be calibrated every 100 determinations or every six months, whichever comes first.
- b. The analytical balances and scales shall be calibrated each year.
- c. The concrete compression machine shall be calibrated annually.
- d. The Blaine apparatus shall be calibrated annually.
- e. All instrumentation used for rapid chemical analysis shall be in accordance with the applicable requirements of ASTM C 114 using NIST reference materials.

d. Certification:

- 310 (1) For Source Approval, the supplier shall furnish a certification indicating the grade of ground granulated blast furnace slag, the name, location, and type of manufacturing facility. It shall state that the ground granulated blast furnace slag shipped for use on Department projects will be produced under appropriate quality control and shall be in accordance with the specified requirements. A sample certification form addressing all of the required information is included in ITM 804.
- 320 (2) For certification of test reports, the test results generated in accordance with 901.03(b) shall be summarized and submitted monthly. The reports shall state the name and location of the testing facility, and shall be signed by the chemist or technical manager. This certification shall also identify the concrete plants receiving ground granulated blast furnace slag represented by these results.

901.04 Silica Fume Used As a Pozzolanic Mineral Admixture.

330 **(a) General.** Silica fume will be accepted from one of the suppliers on the Department's list of approved pozzolanic suppliers. Silica fume from more than one of these suppliers shall not be mixed or used alternately in the same construction unless authorized in writing. Silica fume will be subject to random assurance sampling and testing by the Department. Failure of the random samples to meet the specified requirements will be cause for suspension of the silica fume supplier's approval.

(b) Acceptance Criteria. Acceptance of silica fume will be based on the manufacturer's documented ability to consistently furnish material in accordance with the specified requirements.

340 **1. Requirements.** The silica fume shall be in accordance with AASHTO M 307.

2. Frequency of Testing.

- a. The manufacturer shall obtain a minimum of one sample for each 400 Mg (400 t) of material produced. Test results for moisture content, and loss on ignition, shall be furnished for each sample.
- 350 b. For each 2000 Mg (2000 t) produced, a complete AASHTO M 307 analysis shall be performed on a sample composed randomly from daily samples. The method of randomization shall be subject to approval by the Department. The optional chemical and physical requirements identified in AASHTO M 307 shall be reported in addition to the standard chemical and physical requirements.

3. Test and Calibration Procedure. The minimum frequencies for calibration of test equipment shall be as follows.

- a. The analytical balances and scales shall be calibrated annually.
- b. The concrete compression machine shall be calibrated annually.
- c. The Blaine apparatus shall be calibrated annually.
- d. All instrumentation used for rapid chemical analysis shall be in accordance with AASHTO T 105.

4. Documentation. Silica fume suppliers requesting approval shall supply the following to the Materials and Tests Division:

- a. For initial approval, a current Material Safety Data Sheet and a summary of results for all specified tests for six consecutive months shall be submitted. No test results shall be more than one year old at the time of the request.
- b. To maintain approval, a summary of results for all specified tests shall be submitted monthly.
- c. A quality control program which ensures the Department a continuous supply of silica fume complying with the material requirements and calibration procedures shall be submitted. This program will be reviewed by the Materials and Tests Division to determine its adequacy.
- d. Certification:
 - (1) For approval, the supplier shall furnish a certification indicating the name, location, and type of manufacturing facility, which includes the metallurgical process and furnace. It shall state that the silica fume shipped for use on Department projects will be produced under appropriate quality control and shall be in accordance with the specified requirements. A sample certification is set out in ITM 804.
 - (2) For certification of test reports, the results generated in accordance with 901.04(b) shall be summarized and submitted monthly. The reports shall state the name and location of the testing facility, and shall be signed by the chemist or technical manager. This certification shall also identify the concrete plants receiving silica fume represented by these results.

SECTION 902 – ASPHALT MATERIALS

902.01 Asphalt. Asphalt is defined as a cementitious material obtained from petroleum processes. Asphalts shall be sampled and tested in accordance with the applicable requirements of 902.02.

(a) Performance Graded Asphalt Binders. Performance graded, PG, asphalt binders shall be supplied with a type A certification in accordance with 916 or unless otherwise qualified under the Approved Supplier Certification, ASC, program in accordance with ITM 581. Type A certifications shall be valid for all shipments made for the next 14 calendar days after the sample has been taken, provided no material has been added to the storage tank originally represented by the sample. The type A certification requirements shall remain in effect unless the specified binders have been qualified in accordance with ITM 581.

Performance graded, PG asphalt binders shall be in accordance with the following:

GRADE	PG 52-34	PG 58-28	PG 58-34	PG 64-22	PG 64-28	PG 64-34	PG 70-22	PG 70-28	PG 76-22
ORIGINAL BINDER									
Flash Point, minimum EC	230								
Viscosity, maximum, 3 Pa·s, Test Temp., EC	135								
DSR, G*/sin δ (delta), minimum, 1.00 kPa, Test Temp. @ 10 rad/s, EC	52	58	58	64	64	64	70	70	76
ROLLING THIN FILM OVEN RESIDUE									
Mass Loss, maximum, %	1.00								
DSR, G*/sin δ (delta), minimum, 2.20 kPa, Test Temp. @ 10 rad/s, EC	52	58	58	64	64	64	70	70	76
PRESSURE AGING VESSEL (PAV) RESIDUE									
PAV Aging Temperature EC ⁽¹⁾	90	100	100	100	100	100	100	100	100
DSR, G*/sin δ (delta), maximum, 5000 kPa, Test Temp. @ 10 rad/s, EC	13	19	16	25	22	19	28	25	31
Physical Hardening ⁽²⁾	Report								
Creep Stiffness, S, maximum, 300 MPa, m-value, minimum, 0.300 Test Temp. @ 60 s, EC	-24	-18	-24	-12	-18	-24	-12	-18	-12

⁽¹⁾Oven temperature tolerance shall be " 0.5EC.

⁽²⁾Physical Hardening is performed on a set of asphalt beams according to AASHTO TP 1 Section 13.1, except the conditioning time is extended to 24 h " 10 min at 10EC above the minimum performance temperature. The 24 h stiffness and m-value are reported for information purposes only.

1. Sampling. A binder lot will include only one grade of PG binder. Each sample shall be taken from the asphalt delivery system at the HMA plant. Each sample will be a subplot and all samples taken within a calendar week will be a lot. However, a lot will contain a minimum of three sublots with a maximum of eight sublots. If less than three sublots occur within a calendar week, these sublots will be combined with subsequent production. However, if less than three sublots occur within a three calendar week period, the lot will be considered complete.

The Department will randomly select one subplot from each lot in accordance with ITM 802 for either complete or partial testing. If the subplot selected is in compliance, the lot will be accepted. If the subplot is not in compliance, the material will be adjudicated as a failed material in accordance with in 105.03.

2. Appeals. If the Contractor does not agree with the acceptance test results for the lot, a request may be made in writing for additional testing. The appeal shall be submitted within 30 calendar days of receipt of the Department's written results. The basis of the appeal shall include AASHTO MP1 test results for the specific subplot in question plus test values from all other sublots for the parameters being disputed.

If an appeal is accepted, the Department will conduct additional PG binder tests on two additional subplot samples randomly selected from the lot in question and the backup sample from the original test. The two additional subplot samples and the backup sample will be tested for the failing test parameters. The backup and additional test results for each test will be averaged. The average value for each test will be considered the final lot value. The Contractor will be notified in writing of the additional test results, the final lot values, and the appeal conclusions.

If the appeal is not accepted, the Department will respond to the Contractor stating the grounds for the denial.

(b) Asphalt Emulsions. Asphalt emulsions shall be composed of an intimate homogeneous suspension of a base asphalt, an emulsifying agent, and water. Asphalt emulsions may contain additives to improve handling and performance characteristics. Failure of an emulsion to perform satisfactorily in the field shall be cause for rejection, even though it passes laboratory tests. The grade used shall be in accordance with the table for asphalt emulsions as shown herein.

AE-60 is a medium-breaking, low-penetration, high-asphalt content type, intended for hot plant mixing.

AE-90 is a medium-breaking, moderate penetration, high-asphalt content type, intended for hot and cold plant mixing, road mixing, and seal coats or as otherwise specified.

70 AE-150 is a medium-breaking, moderately soft penetration type, intended for use in surface treating, tack coats, and coating open and dense graded aggregate, or as otherwise specified.

 AE-150-L is a medium-breaking, relatively low-viscosity type. It may be specified in lieu of AE-T or AE-150 when a softer asphalt or greater aggregate penetration is desired. AE-150-L is suitable for sand seals.

80 AE-P is a medium-breaking, very soft asphalt, high-asphalt content type, intended for priming surfaces where penetration of aggregate is required or some softening of existing bituminous surfaces is desirable.

 AE-PL is a medium-slow-breaking, low-viscosity, low-asphalt content type, intended for use as a prime or as dust palative.

 AE-T is a medium-breaking, comparatively low penetration type, intended for tack coats, seed mulching, or as otherwise specified.

 HFRS-2 is a quick-breaking, high-viscosity, high-float, relatively high asphalt content type, intended for seal coats.

90 RS-2 is a quick-breaking, high-viscosity, relatively high-asphalt content type, intended for seal coats.

 The requirements for asphalt emulsions shall be in accordance with the following:

REQUIREMENTS FOR ASPHALT EMULSIONS

Characteristics ⁽¹¹⁾	Grade	RS-2 ⁽²⁾	HFRS-2 ⁽²⁾	AE-60 ⁽¹⁾	AE-90 ⁽²⁾	AE-T ⁽²⁾	AE-150 ⁽²⁾	AE-150L ⁽²⁾	AE-P ⁽²⁾	AE-PL ⁽²⁾⁽⁸⁾
Saybolt-Furol Viscosity, 25EC, s	Min. Max.				50	100	50	100		115
Saybolt-Furol Viscosity, 50EC, s		75-400	75-400				(9)		15-150	
Residue from Res. by Dist., %	Min. Max.	68	68	68	68	54 62	68	60 65	65	30
Oil Portion, from Res. by Dist. ML oil per 100 g, Emul., Max. ⁽³⁾		4.0	4.0	2.0	4.0	4.0	7.0	7.0	25.0	3.0
Settlement, 5 days, %, Max. ⁽⁴⁾		5	5	5	5					
Stone Coating Test ⁽⁵⁾					(5)		(6)	(6)		
Demulsibility, %, Min. ⁽⁷⁾	35 mL, 0.02N CaCl ₂ 50 mL, 0.10N CaCl ₂	50	50	75	75	75				
Sieve Test, % Max. ⁽¹²⁾		0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Res. by Dist. Float Test ⁽⁷⁾	at 50EC, s Max. at 60EC, s Min.		1200	1200	1200	1200	1200	1200	200	
Penetration ⁽⁷⁾ (0.1 mm)	25EC, 100 g, 5 s 25EC, 50 g, 5 s	100-200	100-200	50-100	100-200	50-200	100-300	100-300		
Solubility in Org. Solv., %, Min. ⁽⁷⁾		97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5
Ductility, 25EC, mm, Min. ⁽⁷⁾		400	400	400	400	400				

NOTES: (1) Emulsified asphalt shall be readily pumpable under field conditions. Material may be rejected if Saybolt-Furol viscosity at 50EC exceeds 500 s. (2) Emulsified asphalt shall be readily sprayable under field conditions. (3) The oil distillate shall be in accordance with ASTM D 396, Table 1, Grade 1. (4) This requirement is waived if the emulsion is used within five days. (5) See test (t)3a in 902.02. (6) See test (t)3b in 902.02. (7) The test may be waived by the Engineer. (8) See test (w) in 902.02. (9) AE-150 to be used for crackfilling shall have Saybolt-Furol viscosity from 75 to 300 s at 50EC during the period November through March. (10) The combined percentages of the residue portion, and of the oil portion from the residue by distillation test shall be 70.0%, minimum. (11) The Engineer will determine the feasibility of performing tests on samples that are broken or more than 10 days old. (12) A maximum of 0.30% is acceptable for samples taken at the point of use provided the material remains sprayable.

(c) Cutback Asphalts. Cutback asphalts shall be composed of an intimate homogeneous mixture of an asphalt base and a suitable distillate designed for medium, or slow curing. Cutback asphalts may also contain an additive as an aid in uniformly coating wet, damp, or dry aggregates used in patching mixtures or HMA pavements. These asphalts shall not contain more than 0.3% water as determined by AASHTO T 55, shall not separate when allowed to stand, and shall not foam when heated to permissible temperatures. When an additive is used, it shall be incorporated homogeneously in the asphalt at the point of manufacture. The temperature of the cutback asphalt shall not be higher than shown for that grade in 902.03.

1. Medium Curing Asphalts With and Without Additives. Medium curing asphalts with and without additives shall be in accordance with the following:

Characteristics	Grades			
	MC-70 MCA-70	MC-250 MCA-250	MC-800 MCA-800	MC-3000 MCA-3000
Flash Point (Open Tag.), EC ⁽⁴⁾	38 +	66 +	66 +	66 +
Kinematic Viscosity at 60EC (cSt.) ⁽²⁾	70-140	250-500	800-1600	3000-6000
Saybolt-Furol Viscosity at 50EC (s)	60-120	125-250	100-200	300-600
Saybolt-Furol Viscosity at 60EC (s)				
Saybolt-Furol Viscosity at 83EC (s)				
Distillation ⁽¹⁾				
Distillate (% of total distillate to 360EC MC-70 @ 225EC):				
to 225EC	0-20	0-10		
to 260EC	20-60	15-55	35 +	15 +
to 316EC	65-90	60-87	45-80	15-75
Residue from distillation to 360EC (volume % by difference)	55 +	67 +	75 +	80 +
Tests on Residue from Distillation: ⁽¹⁾				
Penetration, 25EC, 100 g, 5 s - (0.1mm)				
(without additive)	120-250	120-250	120-250	120-250
(with additive)	120-300	120-300	120-300	120-300
Ductility, 25EC (10 mm) ⁽³⁾	100 +	100 +	100 +	100 +
Solubility in organic solvents, %	99.5 +	99.5 +	99.5 +	99.5 +

(1) Test may be waived when approved.

(2) Viscosity may be determined by either the Saybolt-Furol or Kinematic test. In case of dispute, the Kinematic viscosity test shall prevail.

(3) If the ductility at 25EC is less than 100, the material will be acceptable if its ductility at 16EC is 100 + .

(4) Flash point by Cleveland Open Cup may be used for products having a flash point greater than 80EC.

2. Slow Curing Asphalts With and Without Additives. Slow curing asphalts with and without additives shall be in accordance with the following:

Characteristics	Grades			
	SC-70 SCA-70	SC-250 SCA-250	SC-800 SCA-800	SC-3000 SCA-3000
Flash Point (Cleveland Open Cup), (EC)	66 +	79 +	93 +	107 +
Kinematic Viscosity at 60EC (cSt) ⁽²⁾	70-140	250-500	800-1600	3000-6000
Saybolt-Furol Viscosity at 50EC (s)	60-120	125-250	100-200	300-600
Saybolt-Furol Viscosity at 60EC (s)				
Saybolt-Furol Viscosity at 83EC (s)				
Distillation ⁽¹⁾				
Total Distillate to 360EC (% by volume)	10-30	4-20	2-12	5
Float Test of Distillation Residue at 50EC (s)	20-100	25-110	50-140	75-200
Ductility of Asphalt Residue at 25EC (10 mm) ⁽¹⁾	100 +	100 +	100 +	100 +
Solubility in organic solvents, % ⁽¹⁾	99.5 +	99.5 +	99.5 +	99.5 +

(1) Test may be waived when approved.

(2) Viscosity may be determined by either the Saybolt-Furol or Kinematic test. In case of dispute, the Kinematic viscosity test shall prevail.

130 **(d) Utility Asphalt.** The asphalts shall be uniform in character and shall not foam when heated to 177EC (350EF). Utility asphalts shall be in accordance with the following:

Characteristics/Grades	UA-I	UA-II	UA-III
Softening Point (Ring & Ball), EC	46-63	63-85	79.5-96
Penetration of Original Samples ⁽¹⁾ (0.1 mm) at 4EC, 200 g, 60, s Min. at 25EC, 100 g, 5 s at 46EC, 50 g, 5 s	10 50-100 100 Min.	10 25-45 130 Max.	10 15-35 90 Max.
Ductility @ 25EC, 50 mm/min, 10 mm, Min. ⁽¹⁾	30	10	2.5
Solubility in Organic Solvents, percent, Min. ⁽¹⁾	99.0	99.0	99.0
Flash Point (Cleveland Open Cup), EC, Min. ⁽¹⁾	225	225	225
Penetration of Residue from Thin Film Oven Test, 25EC, 100 g, 5 s, (0.1 mm) Min. ⁽¹⁾	30	15	10

(1) Test will be performed when complete physical characteristics are needed or desired.

(e) Asphalt for Coating Corrugated Metal Pipe. Asphalt for coating corrugated metal pipe shall be in accordance with the following:

Physical Properties	Minimum	Maximum
Softening Point (Ring & Ball), EC	93	110
Penetration of Original Samples (0.1 mm) at 4EC, 200 g, 60 s, Min. at 25EC, 100 g, 5 s	20 35 ⁽¹⁾	
Solubility in Organic Solvents, %	99.0	
Flash Point (Cleveland Open Cup), EC	232	
Flow Test, mm		6.4
Shock Test	3 of 4 specimens shall pass	

(1) May be 30 minimum provided all four shock test specimens pass.

140 **902.02 Sampling and Testing Asphalt Materials.** The tests and AASHTO reference are as follows:

(a) Sampling Bituminous MaterialsAASHTO T 40
The following exceptions to AASHTO T 40 shall apply:

1. Samples may be obtained at any time before material is incorporated into the work.
2. Samples for all grades of asphalt emulsion shall be a minimum of 1.9 L (1/2 gal.). The size of samples of other liquid material may be 1.0 L (1 qt).
3. Samples of liquid materials shall be obtained as follows:
 - a. bulk storage tanks from approved sampling valves located in the tank or line and asphalt plant storage tanks from approved sampling valves located in the tank
 - b. transports from approved sampling valves
 - c. distributors from approved sampling valves
 - d. other storage or locations as approved
 - e. sampling by other recognized devices may be approved

(b) Water in petroleum products, except the solvent
or carrier may be tolueneAASHTO T 55

(c) Density, Specific Gravity, or API Gravity of
Crude Petroleum and Liquid Products by
Hydrometer Method..... AASHTO T 227

	(d) Specific Gravity of Semi-Solid Bituminous Materials.....	AASHTO T 228
	(e) Specific Gravity of Solid Pitch and Asphalt	AASHTO T 229
	(f) Flash and Fire Points (Open Cup)	
180	1. When the flash point is higher than 79EC (175EF), "Flash and Fire Points by Cleveland Open Cup"	AASHTO T 48
	2. When the flash point is 79EC (175EF) or lower, "Flash Point with Tagliabue Open Cup"	AASHTO T 79
	(g) Softening Point of Bituminous Materials, Ring and Ball	AASHTO T 53
190	(h) Penetration of Bituminous Materials	AASHTO T 49
	(i) Loss on Heating	AASHTO T 47
	(j) Solubility in Organic Solvents, except the solvent may be 1,1,1,-Trichloroethane	AASHTO T 44
	(k) Inorganic Matter or Ash	AASHTO T 59
200	(l) Saybolt-Furol Viscosity.....	AASHTO T 72
	(m) Ductility of Binder Material, except that the conditioning period of the specimens may be shortened, and that only one normal test will be required. Shortened conditioning period: The specimen shall be allowed to cool in air for at least 30 min. It shall then be trimmed and placed in the water bath for a period of 60 to 90 min before testing. In case of failure or dispute, three normal tests will be required and specimens shall be conditioned as in AASHTO T 51	
210	(n) Distillation of Cutback Asphaltic Products, except the length of condenser tube may be 400 mm " 24 mm	AASHTO T 78
	(o) Float Test for Bituminous Materials.....	AASHTO T 50
	(p) Kinematic Viscosity of Asphalts	AASHTO T 201
	(q) Absolute Viscosity of Asphalts	AASHTO T 202
220	(r) Effect of Heat and Air on Asphalt Materials, Thin-Film Oven Test.....	AASHTO T 179

- (s) Effect of Heat and Air on a Moving Film of
Asphalt, Rolling Thin Film Oven Test AASHTO T 240
- (t) Testing Asphalt EmulsionsAASHTO T 59
The following exceptions to T 59 shall apply:

1. For the Residue by Distillation test, the specified aluminum alloy
still shall be the referee still.

2. When tests on the residue are not required, the percent of residue for
emulsion grades RS-2, AE-60, AE-90, and AE-T only, may be
determined by the Residue by Evaporation test of AASHTO T 59.
The percent of residue shall be determined by the Residue of
Distillation test in all cases of failure or dispute.

3. The stone coating test shall be performed as follows on a mixture of
465 " 1 g of reference stone and 35.0 " 0.1 g of asphalt emulsion:

a. For AE-90 the mixture of stone and asphalt shall be mixed
vigorously for 5 min. At the end of the mixing period, the mix
shall be rinsed by running sufficient tap water at the side of the
container to completely immerse the mix. The tap water shall then
be poured off and the rinsing step repeated as necessary until the
rinse water pours off essentially clear. The stone shall remain a
minimum of 90% coated.

b. For AE-150 and AE-150-L, the mixture of stone and asphalt shall
be mixed vigorously for 5 min and then allowed to stand for 3 h.
At the end of this time, the mixture shall again be mixed
vigorously for 5 min. At the end of the mixing period, the mix
shall be rinsed by running sufficient tap water at the side of the
container to completely immerse the mix. The tap water shall then
be poured off and the rinsing step repeated as necessary until the
rinse water pours off essentially clear. The stone shall remain a
minimum of 90% coated for AE-150 and AE 150-L.

4. For the Demulsibility test, normally only one test will be required.
In case of failure or dispute, the specified procedure in AASHTO
T 59 will be followed.

5. For oil portion from Residue by Distillation, report the number of
milliliters of oil per 100 g of emulsion.

(u) For coating test for cutback asphalts with additive, 20 g of 20 to 30 mesh Ottawa sand shall be placed in a clean 60 mL (2 oz) wide-mouthed jar and covered with 25 g of distilled water at room temperature. One gram of the liquid asphalt to be tested shall be placed gently upon the surface of the water so that it floats and does not contact the sand. The lid shall then be placed on the jar and tightened securely. If the liquid asphalt to be tested is grade 70 or 250, the jar and contents shall be shaken vigorously for 30 s. If the grade is 800 or 3000, the jar and contents shall be immersed in a 46EC (115EF) water bath for 5 min to bring the contents of the jar to a temperature of approximately 38EC (100EF). The jar shall then be shaken vigorously for 30 s. After shaking, the asphalt coating on the sand shall be observed under a constant, strong light. Complete coating of the sand is required.

(v) Stripping tests for HMA mixtures using binder materials, with or without additives, shall be performed as follows:

1. Test 1. A sample of produced mixture, 500 g, minimum, shall be obtained for testing. The size of test specimen and the amount of distilled water shall be:

Approximate Size of Aggregate	Minimum Weight of Test Specimen	Amount of Distilled Water
Sand	100 g	400 mL
12	100 g	400 mL
11	150 g	600 mL
9	200 g	600 mL

Place the specimen in the boiling distilled water and stir with a glass rod at the rate of one revolution per second for 3 min. The aggregate shall retain a minimum of 90% of its asphalt film compared with the remainder of the sample, upon completion of this procedure.

2. Test 2. Approximately 500 g of produced mixture shall be heated to 121EC (250EF) in a laboratory oven for 2 h; stirred and cooled to 92.5EC (200EF). Then a portion of the mix shall be placed in boiling distilled water, quantity of mix and quantity of boiling water shall be as specified in Test 1, and stirred with a glass rod at the rate of one revolution per second for 3 min. The aggregate shall retain a minimum of 90% of its asphalt film compared with the remainder of the sample, upon completion of this procedure.

Note: The purpose of these tests is to determine the relative compatibility of the aggregate and asphalt, and to detect tendency of Asphalt Emulsions to reemulsify. Test 2 may be performed as a method of determining whether compatibility can be achieved, Test 1 having given unsatisfactory results.

(w) Penetrating Ability of AE-PL.

1. Apparatus and Equipment:

a. Sand mixture:

- 320 (1) Dry Standard Ottawa Sand (AASHTO T 106)90 parts
- (2) Dry Reference Limestone Dust, portion passing 300 mm (#50) sieve only. Reference Limestone Dust used by the Department is Limestone Calcium Carbonate manufactured by France Stone Co. The Department will furnish approximately 2.3 kg (5 lb) of Reference Limestone Dust upon request10 parts
- (3) Water 3 parts

330 b. Container, 170 g (6 oz) ointment tin

c. Ruler or other measuring device

d. Timing device readable in seconds

340 e. Compacting Device. Rimac Spring Tester or other device suitable for compacting sand by applying a 140 kPa (20 psi) load. The compacting device shall include an adapter consisting of two metal discs slightly smaller in diameter than a 170 g (6 oz) ointment tin separated by a spacer 25 to 50 mm (1 to 2 in.). The 65 mm (2.5 in.) diameter discs used in determining weight of coating in AASHTO T 65 or ASTM A 90 are satisfactory.

f. Small, square ended spatula or putty knife

2. Procedure:

350 Thoroughly mix Standard Ottawa Sand, Reference Limestone Dust, and water. Weigh 190 " 1 g of sand mixture into a 170 g (6 oz) ointment tin. Level surface of sand with a spatula. Place the compacting adapter on the sand surface and slowly, over a period of about 5 s, compact the sand until the 140 kPa (20 psi) load is achieved, which is approximately 45 kg (100 lb) on the Rimac Spring Tester. Remove the compacting device, avoiding disturbance to the sand surface. Quickly pour 12 g of the emulsion from a height of about 100 mm (4 in.) onto top of sand mixture. Start timer at start of pour. Stop timer when all emulsion penetrates into sand mixture. Delay 2 min, then remove sand and mixture from one side of ointment tin, about 1/2 of mixture. Measure to determine average

360 depth of penetration into sand mixture. Penetration time shall be 100 s or less; penetration depth shall be 6 mm (1/4 in.) or more.

	(x) Flow Test for Asphalt for Coating Corrugated Metal Pipe	AASHTO M 190
	(y) Shock Test for Asphalt for Coating Corrugated Metal Pipe	AASHTO M 190
370	(z) Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus	AASHTO TP 48
	(aa) Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer	AASHTO TP 5
	(bb) Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel	AASHTO PP 1
380	(cc) Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer....	AASHTO TP 1

902.03 Application Temperatures. Binder materials for the several applications indicated in the specifications shall be applied at temperatures not to exceed those shown in the following:

Type and Grade of Material	Maximum Application Temperature EC (EF)	
	Spray	Mix
MC-70, MCA-70.....	66 (150)	
MC-250, MCA-250	107 (225)	93 (200)
MC-800, MCA-800	121 (250)	107 (225)
MC-3000, MCA-3000	135 (275)	121 (250)
SC-70, SCA-70.....	93 (200)	
CS-250, SCA-250	107 (225)	107 (225)
SC-800-3000, SCA-800-3000	121 (250)	121 (250)
All Emulsions	71 (160)	82 (180)
All Penetration and Viscosity, Utility and Pipe Coating	177 (350)	163 (325)
PG Binders	Note (1)	Note (1)

Note (1): In accordance with manufacturer's recommendations.

SECTION 903 – CLASSIFICATION OF SOILS

903.01 Definitions. All of the soils shall be tested and classified in accordance with AASHTO M 145, and in accordance with the grain-size classification procedure as follows:

Soil Classification	Definition
Boulders	Retained on 75 mm (3 in) sieve
Gravel	75 mm (3 in) to 2.0 mm (No. 10) sieve
Coarse Sand	2.00 mm (No. 10) to 425 :m (No. 40) sieve
Fine Sand	425 :m (No. 40) to 75 :m (No. 200) sieve
Silt	0.075 to 0.002 mm
Clay	Smaller than 0.002 mm
Colloids	Smaller than 0.001 mm

903.02 Soils Having 0% to 19% Retained on 2.00 mm (No. 10) Sieve. These soils shall be classified as follows:

10

Classification	Percent Sand and Gravel	Percent Silt	Percent Clay
Sand	80 - 100	0 - 20	0 - 20
Sandy Loam	50 - 80	0 - 50	0 - 20
Loam	30 - 50	30 - 50	0 - 20
Silty Loam	0 - 50	50 - 80	0 - 20
Silt	0 - 20	80 - 100	0 - 20
Sandy Clay Loam	50 - 80	0 - 30	20 - 30
Clay Loam	20 - 50	20 - 50	20 - 30
Silty Clay Loam	0 - 30	50 - 80	20 - 30
Sandy Clay	50 - 70	0 - 20	30 - 50
Silty Clay	0 - 20	50 - 70	30 - 50
Clay	0 - 50	0 - 50	30 - 100

903.03 Soils Having 20% or More Retained on 2.00 mm (No. 10) Sieve and More Than 20% Passing 75 Fm (No. 200) Sieve. These soils shall be classified in accordance with 903.02, followed by a term describing the relative amount of gravel as follows:

20% to 35%:	"with some gravel"
36% to 50%:	"and gravel"

903.04 Soils Having 20% or More Retained on 2.00 mm (No. 10) Sieve and Less Than 20% Passing 75 Fm (No. 200) Sieve. These soils shall be classified as follows:

Classification	Percent Gravel	Percent Sand	Percent Silt	Percent Clay
Gravel	85 - 100	0 - 15	0 - 15	0 - 15
Sandy Gravel	40 - 85	15 - 40	0 - 20	0 - 20
Gravelly Sand	20 - 40	40 - 80	0 - 20	0 - 20
Sand & Gravel	20 - 50	20 - 50	0 - 20	0 - 20

If the gradation of a given sample is not in exact accordance with the requirements for a given classification, it shall be placed in the classification to which it comes the closest.

903.05 Organic Soils. The following classification system shall be used for organic soils in accordance with AASHTO T 267.

Classification	Percentage
With Trace Organic Matter	1 to 6
With Little Organic Matter	7 to 12
With Some Organic Matter	13 to 18
Organic Soil (A-8)	19 - 30
Peat (A-8)	More than 30

903.06 Marly Soils. The following classification system shall be used for marly soils with calcium and magnesium carbonate content.

Classification	Percentage
With Trace Marl	1 to 9
With Little Marl	10 to 17
With Some Marl	18 to 25
Marly Soil (A-8)	26 to 40
Marl (A-8)	More than 40

SECTION 904 – AGGREGATES

904.01 Fine Aggregates. Fine aggregates shall consist of natural sand or manufactured sand produced by crushing limestone, dolomite, steel furnace (SF) slag, air cooled blast furnace (BF) slag, granulated blast furnace (GBF), or wet bottom boiler slag. Natural sand, which has been used as foundry sand, may be used in precast concrete units and precast concrete pipe. At time of use fine aggregate shall be free from lumps or crusts of hardened or frozen materials and shall be in accordance with the specifications as set out herein.

No source will be considered for acceptance of material until a preliminary investigation has been made. As part of this investigation, samples will be taken and tests conducted to determine the quality of the aggregates.

Fine aggregates, except for fine aggregates used for snow and ice abrasive or precast concrete units, shall be supplied by a Certified Aggregate Producer in accordance with 917.

(a) For Portland Cement Concrete. Fine aggregate for use in portland cement concrete pavement or bridge decks shall be natural sand. Fine aggregate for other portland cement concrete shall be natural sand or crushed limestone, dolomite, or air-cooled blast furnace slag. The gradations shall be in accordance with 904.01(g) and shall be well graded from coarse to fine.

Foundry sand complying with IDEM Class III or Class IV in accordance with 329 IAC 10-7-4 may be used in precast concrete units or precast concrete pipe. If the precast concrete manufacturer elects to use such foundry sand, a copy of the Waste Classification issued by IDEM and an indemnification statement shall accompany the items to each contract.

The sand shall have not more than 3% of organic impurities. When subjected to the colorimetric test for organic impurities and a color darker than the standard is produced, it shall be tested for effect of organic impurities on strength of mortar in accordance with AASHTO T 71. If the relative strength at seven days is less than 95% it shall be rejected. When the sand is subjected to five cycles of the sodium sulphate soundness test or 25 cycles of the brine freeze-and-thaw soundness test, the weighted loss shall not exceed 10.0% by weight or 12.0% by weight, respectively. Fine aggregates may, at the option of the Engineer, be subjected to 50 cycles of freezing and thawing in accordance with AASHTO T 103, Procedure A, and may be accepted, provided they do not have a loss greater than specified for sodium sulfate soundness.

(b) For HMA Mixtures. Fine aggregates for use in HMA mixtures shall consist of natural sand or manufactured sand having similar characteristics, except SF slag sand will only be permitted when the coarse aggregate is SF slag. A combination of natural sand and manufactured sand will be permitted when approved; however, not more than 20% of the total aggregate used in HMA surface mixtures shall be crushed limestone sand. Windblown sand or similar sands will not be acceptable for blending. The fine aggregate, including blended fine aggregate, used in HMA Surface 4.75 mm mixtures shall have a minimum Florida Bearing Value of 30. The fine aggregate, including blended fine aggregate, used in HMA Surface 4.75 mm mixtures shall have a minimum acid insoluble content of 40%, except when using ABF or GBF slag sand, the minimum acid insoluble content shall be 25%. Fine aggregates shall be in accordance with 904.01(a) for soundness. The mass (weight) adjustment in accordance with 904.02(a) will be applied to fine aggregate only when manufactured from SF slag.

The fine aggregate angularity value of the blended aggregate material from the fine and coarse aggregates shall meet or exceed the minimum values for the appropriate ESAL category shown on the title sheet and position within the pavement structure as follows:

60

FINE AGGREGATE ANGULARITY		
TRAFFIC, ESAL	DEPTH FROM SURFACE	
	< 100 mm	> 100 mm
< 300,000		
< 1,000,000	40	
< 3,000,000	40	40
< 10,000,000	45	40
< 30,000,000	45	40
< 100,000,000	45	45
> 100,000,000	45	45

Fine Aggregate Angularity, Method A AASHTO T 304

The clay content of the blended aggregate material from the fine and coarse aggregates shall meet or exceed the minimum values for the appropriate ESAL category shown on the title sheet as follows:

CLAY CONTENT	
TRAFFIC, ESAL	SAND EQUIVALENT, MINIMUM
< 300,000	40
< 1,000,000	40
< 3,000,000	40
< 10,000,000	45
< 30,000,000	45
< 100,000,000	50
> 100,000,000	50

Clay Content, Sand Equivalency AASHTO T 176

70

(c) For Pneumatic Placement. Fine aggregate for use in pneumatic placement shall be natural sand suitable for use with a pneumatic sand cement gun. It shall be in accordance with the requirements for organic impurities and soundness as set out in 904.01(a). It may be in accordance with 904.01(g), size No. 15, or the following gradation:

Sieve Size No.	4.75 mm (4)	2.36 :m (8)	600 :m (30)	300 :m (50)	150 :m (100)
Percent Passing	100	85-95	50-65	15-25	0-10

80 **(d) For Mortar.** Fine aggregate for mortar shall consist of natural sand. It shall be graded uniformly from coarse to fine and shall be in accordance with gradation requirements of 904.01(g) for size No. 15. It shall be in accordance with 904.01(a) for organic impurities and soundness.

90 **(e) Mineral Filler.** Mineral filler shall consist of dust produced by crushing stone, portland cement, fly ash, or other inert mineral matter having similar characteristics for use in HMA. It shall be in accordance with the gradation requirements of 904.01(g) for size No. 16. Fly ash shall have been collected by means of an electrostatic precipitation method and shall not contain free carbon in excess of 10% by mass (weight). The sieve analysis of mineral filler shall be conducted in accordance with AASHTO T 37 except as noted in 904.03.

(f) Snow and Ice Abrasives. Snow and ice abrasives shall be steel furnace slag, air cooled blast furnace slag, granulated blast furnace slag, boiler slag, natural sand, crushed stone sand, or cinders. The abrasives shall pass the following gradation requirements:

Passing the 9.5 mm (3/8 in.) sieve 100%
 Passing the 300 Fm (No. 50) sieve 0-30%
 Passing the 75 Fm (No. 200) sieve 0-7%

100 When steel slag is used as snow and ice abrasives, and payment is on a tonnage basis, the pay quantity shall be adjusted in accordance with 904.02(a).

(g) Sizes of Fine Aggregates.

Sieve Sizes	SIZES (PERCENTS PASSING)			
	23	24	15	16
9.5 mm (3/8 in.)	100	100		
4.75 mm (No. 4)	95-100	95-100		
3.35 mm (No. 6)			100	
2.36 mm (No. 8)	80-100	70-100	90-100	
1.18 mm (No. 16)	50-85	40-80		
600 :m (No. 30)	25-60	20-60	50-75	100
300 :m (No. 50)	5-30	7-40	15-40	
180 :m (No. 80)				95-100
150 :m (No. 100)	0-10	1-20	0-10	
75 :m (No. 200)	0-3	0-6	0-3	65-100

Note: The fine aggregate shall have not more than 45% retained between any 2 consecutive sieves.

(h) Sampling and Testing. Sampling and testing shall be conducted in accordance with the following AASHTO and ITMs:

110	Acid Insoluble Content	ITM 202
	*Amount of Material Finer than	
	75 Fm (No. 200) sieve	AASHTO T 11
	Brine Freeze-and-Thaw Soundness.....	ITM 209
	Control Procedures for Classification of Aggregates.....	ITM 203
	Florida Bearing Value	ITM 201
	Mortar Strength	AASHTO T 71
	Organic Impurities	AASHTO T 21
	*Sampling Aggregates	AASHTO T 2
	Sampling Stockpiled Aggregates	ITM 207
120	*Sieve Analysis of Aggregate.....	AASHTO T 27
	*Sieve Analysis of Mineral Filler.....	AASHTO T 37
	*Soundness	AASHTO T 103, T 104
	Specific Gravity and Absorption, Fine Aggregate	AASHTO T 84
	*Except as noted in 904.03.	

904.02 Coarse Aggregates.

(a) General Requirements. Coarse aggregates shall consist of crushed limestone or dolomite; crushed or uncrushed gravel; crushed steel furnace (SF) slag or air cooled blast furnace (BF) slag; or sandstone. When dolomite coarse aggregates are used in accordance with 401.03 or 402.02, the material furnished shall be carbonate rock containing at least 10.3% elemental magnesium when tested as set out in ITM 205. Coarse aggregates shall not contain more than 10% flat and elongated pieces and shall not contain particles with an adherent coating. A flat and elongated piece is defined as a particle having a ratio of length to thickness greater than five.

Sandstone may be used only in HMA surface mixtures. Sandstone for this use shall be in accordance with the Class B quality requirements. Sandstone is defined as a sedimentary rock composed of siliceous sandgrains containing quartz, chert, and quartzose rock fragments in a carbonate matrix or cemented with silica, calcite, or dolomite. Identification of a sandstone will be determined by the Materials and Tests Division.

Steel furnace (SF) slag may be used in compacted aggregate shoulders in accordance with 303, in surface mixtures with Asphalt Emulsion in accordance with 402, in HMA surface mixtures in accordance with 402, as dumped riprap in accordance with 904.04(a), and for snow and ice abrasives in accordance with 904.01(f).

150 When slag is furnished as an alternate to natural aggregate, and payment is on a mass (weight) basis, adjustments shall be made to compensate for the difference in specific gravity of the slag compared to natural aggregate. The following typical values for specific gravity will be used: natural aggregate both fine and coarse, 2.6; air cooled blast furnace (ABF) slag coarse aggregate, 2.3; air cooled blast furnace (ABF) slag fine aggregate, 2.6; granulated blast furnace (GBF) slag fine aggregate, 2.1; and steel furnace (SF) slag both fine and coarse, 3.2. The adjustment shall not apply to aggregates or HMA mixture used for approaches or patching.

When slag is furnished as an ingredient of a HMA mixture, the adjustment shall be applied as follows:

- 160 1. Determine the amount of natural aggregate in the mixture using the following formula:

$$A = T(1 - \%B)$$

A = Megagrams (tons) of natural aggregate in the mixture.

T = Pay item quantity in megagrams (tons) for the specified mixture.

%B = Percent bitumen as decimal from the job mix formula.

%FA = Percent passing 4.75 mm (No. 4) sieve as a decimal from the JMF.

170 %CA = Percent retained on 4.75 mm (No. 4) sieve as a decimal from the JMF.

2. Determine the amount of slag required for coarse aggregate (CAS) by the following formula:

$$CAS = A(\%CA) (\text{SpGr Slag}/2.6)$$

3. Determine the amount of slag required for fine aggregate (FAS) by the following formula:

180
$$FAS = A(\%FA) (\text{SpGr Slag}/2.6)$$

4. Determine the adjusted quantity in megagrams (tons) (TAS) by the following formula:

$$TAS = T(\%B) + CAS + \text{Weight of fine aggregate used}$$

5. Adjust the design lay in kilograms per square meter (lb per sq yd) by the following formula:

190
$$\text{Adjusted lay} = (\text{Design Lay}) (TAS/T)$$

6. Determine adjusted pay quantity by the following formula:

$$\text{Adjusted pay quantity} = (\text{accepted megagrams [tons]}) (T/TAS)$$

200 When slag is furnished as an aggregate, the approximate quantity of megagrams (tons) to be supplied will be determined by multiplying the pay item quantity of megagrams (tons) by the specific gravity of slag divided by 2.6. The adjusted pay quantities will be determined by multiplying the accepted quantity of megagrams (tons) by 2.6 divided by the specific gravity of the slag.

Crushed gravel shall have a minimum of one angular fractured face, such as a broken surface, which was caused mechanically or naturally. Natural fractures and mechanical fractures shall be the same in texture and effect. An acceptable fractured area shall have at least 25% of the largest cross sectional area of the particle as specified in ITM 204.

210 Recycled portland cement concrete may be used in compacted aggregate base in accordance with 303. Recycled portland cement concrete shall be in accordance with quality and gradation requirements. If recycled portland cement concrete pavement is used from within the project limits, only the gradation requirements will apply.

No source will be considered for acceptance of material until a preliminary investigation has been made. As part of this investigation, samples will be obtained and tests conducted to determine the classification of the aggregates. There are two types of samples required for the preliminary investigation; namely, ledge samples for crushed stone sources and production samples for crushed stone, gravel, and slag sources.

220 Ledge samples will be obtained from the bedrock units as they naturally occur in the proposed working face of the quarry. These units will be identified by their differences in color, texture, geological formation, etc.

Production samples will be obtained from stockpiles of finished materials.

230 The coarse aggregate shall comply with the quality requirements and the additional requirements as shown in the following table. However, coarse aggregate may be rejected based on previous performance service records. Class A is defined as the highest classification and class F the lowest. Blending of material for compliance with gradation or crushed particle requirements may be permitted when requested in writing. Blending a material which does not meet the quality or deleterious requirements with a better material to upgrade the end product will not be permitted.

Classification of finished products offered for use will be made in accordance with ITM 203.

Coarse aggregates, except for coarse aggregates used for precast concrete units, shall be supplied by a Certified Aggregate Producer in accordance with 917.

(b) Classification of Aggregates.

Characteristic Classes	AP	A	B	C	D	E	F
Quality Requirements							
Freeze-and-Thaw Beam Expansion, % Max. (Note 9).....	.060						
Los Angeles Abrasion, %, Max. (Note 1).....	40.0	40.0	40.0	45.0	45.0	50.0	
Sodium Sulfate Soundness, %, Max. (Note 2).....	12.0	12.0	12.0	16.0	16.0	20.0	25.0
Brine Freeze-and-Thaw Soundness, % Max. (Note 8).....	30	30	30	40	40	50	60
Absorption, %, Max. (Note 3)	5.0	5.0	5.0	5.0			
Additional Requirements							
Deleterious, %, Max.							
Clay Lumps and Friable Particles	0.2	0.2	0.2	0.2	0.2		
Non-Durable (Note 4)	4.0	4.0	4.0	6.0	8.0		
Coke				(See Note 7)	(See Note 7)		
Iron				(See Note 7)	(See Note 7)		
Chert (Note 5)	3.0	3.0	5.0	8.0	10.0		
Mass Per Cubic Meter for Slag, kg,	1200	1200	1200	1120	1120	1120	
Weight Per Cubic Foot for Slag, (lbs), Min.	(75.0)	(75.0)	(75.0)	(70.0)	(70.0)	(70.0)	
Crushed Particles, %, Min. (Note 6)							
Asphalt Seal Coats		70.0	70.0				
Compacted Aggregates		20.0	20.0	20.0	20.0		

- NOTES: 1. Los Angeles abrasion requirements shall not apply to blast furnace slag.
2. Aggregates may, at the option of the Engineer, be subjected to 50 cycles of freezing and thawing in accordance with AASHTO T 103, Procedure A, and may be accepted, provided they do not have a loss greater than specified for Sodium Sulfate Soundness.
3. Absorption requirements apply only to aggregates used in portland cement concrete and HMA mixtures except they shall not apply to blast furnace slag. When crushed stone coarse aggregates from Category I sources consist of production from ledges whose absorptions differ by more than two percentage points, the absorption test will be performed every three months on each size of material proposed for use in portland cement concrete or HMA mixtures. Materials having absorption values between 5.0 and 6.0 that pass AP testing may be used in portland cement concrete. If variations in absorption preclude satisfactory production of portland cement concrete or HMA mixtures, independent stockpiles of materials will be sampled, tested, and approved prior to use.
4. Non-durable particles include soft particles as determined by ITM 206 and other particles which are structurally weak, such as soft sandstone, shale, limonite concretions, coal, weathered schist, cemented gravel, ocher, shells, wood, or other objectionable material. Determination of non-durable particles shall be made from the total mass (weight) of material retained on the 9.5 mm (3/8 in.) sieve. Scratch Hardness Test shall not apply to crushed stone coarse aggregate.
5. The bulk specific gravity of chert shall be based on the saturated surface dry condition. The amount of chert less than 2.45 bulk specific gravity, shall be determined on the total mass (weight) of material retained on the 9.5 mm (3/8 in.) sieve for sizes 1 through 8, 53, and 91 and on the total mass (weight) of material retained on the 4.75 mm (No. 4) sieve for sizes 9 and 11.
6. Crushed particle requirements will apply to gravel coarse aggregates used in HMA mixtures, compacted aggregates, and asphalt seal coats except seal coats used on shoulders. Crushed particle requirements for HMA mixtures are set out in 904.02(c). Determination of crushed particles shall be made in accordance with ASTM D 5821.
7. Air-cooled blast furnace slag and steel slag coarse aggregate shall be free of objectionable amounts of coke and iron.
8. Brine freeze-and-thaw soundness requirements are subject to the conditions stated in note 2.
9. Freeze-and-thaw beam expansion shall be tested and retested in accordance with ITM 210.

(c) Coarse Aggregate Angularity. The coarse aggregate shall not contain flat and elongated particles exceeding the maximum value for the appropriate ESAL category shown on the title sheet as follows:

FLAT AND ELONGATED PARTICLES	
TRAFFIC, ESAL	PERCENT, MAXIMUM
< 300,000	
< 1,000,000	
< 3,000,000	10
< 10,000,000	10
< 30,000,000	10
< 100,000,000	10
> 100,000,000	10

Flat and Elongated Particles..... ASTM D 4791

The angularity value of the coarse aggregate shall meet or exceed the minimum values for the appropriate ESAL category shown on the title sheet and position within the pavement structure as follows:

280

COARSE AGGREGATE ANGULARITY		
TRAFFIC, ESAL	DEPTH FROM SURFACE	
	< 100 mm	> 100 mm
< 300,000	55	
< 1,000,000	65	
< 3,000,000	75	50
< 10,000,000	85/80*	60
< 30,000,000	95/90*	80/75*
< 100,000,000	100/100*	95/90*
> 100,000,000	00/100*	100/100*

* Denotes two faced crush requirements

Coarse Aggregate Angularity..... ASTM D 5821

(d) Surface Aggregate Requirements. The surface aggregate selection shall be based on the ESAL loadings for the project as following:

COARSE AGGREGATE TYPES FOR HMA SURFACE MIXTURES (Note 1)			
Coarse Aggregate Type	Traffic ESAL		
	< 1,000,000	< 3,000,000	> 3,000,000
Air-Cooled Blast Furnace Slag	Yes	Yes	Yes
Steel Furnace Slag	Yes	Yes	Yes
Sandstone	Yes	Yes	Yes
Crushed Dolomite	Yes	Yes	Note 2
Crushed Stone	Yes	No	No
Gravel	Yes	No	No

Note 1. Coarse aggregate for HMA shoulder surface mixtures may be any of the coarse aggregate types.

Note 2. A maximum of 50% of coarse aggregate may be dolomite.

(e) Sizes of Coarse Aggregates.

Sieve Sizes	COARSE AGGREGATE SIZES (PERCENTS PASSING)									
	1	2	5	8	9	11	12	53 ⁽¹⁾	73 ⁽¹⁾	91
100 mm (4 in.)	100									
90 mm (3 1/2 in.)	90-100									
63 mm (2 1/2 in.)	25-60	100								
50 mm (2 in.)		95-100								
37.5 mm (1 1/2 in.)	0-15		100					100		
25 mm (1 in.)		0-20	85-98	100				80-100	100	100
19 mm (3/4 in.)	0-5	0-5	60-85	75-95	100			70-90	90-100	
12.5 mm (1/2 in.)		0-2	30-60	40-70	60-85	100	100	55-80	60-90	
9.5 mm (3/8 in.)			15-45	20-50	30-60	75-95	95-100			
4.75 mm (No. 4)			0-15	0-15	0-15	10-30	50-80	35-60	35-60	
2.36 mm (No. 8)			0-10	0-10	0-10	0-10	0-35	25-50		
600 :m (No. 30)							0-4	12-30	12-30	
75 :m (No. 200)(2)								5.0-10.0	5.0-12.0	
Decant Conc ⁽³⁾			0-1.5	0-1.5	0-1.5	0-1.5				0-1.5
Other	0-1.0	0-2.5	0-2.5	0-3.0	0-2.5	0-2.5	0-2.0			0-2.5

NOTES: 1. The fraction passing the 75 Fm (No. 200) sieve shall not exceed 2/3 the fraction passing the 600 Fm (No. 30) sieve. The liquid limit shall not exceed 25 (35 if slag) and the plasticity index shall not exceed 5. The liquid limit shall be determined in accordance with AASHTO T 89 and the plasticity index in accordance with AASHTO T 90.

2. Includes the total amount passing the 75 Fm (No. 200) sieve as determined by AASHTO T 11 and T 27.

3. When the material is stone or slag, the decant may be 0 to 2.5.

(f) Sampling and Testing. Sampling and testing shall be in accordance with the following AASHTO and ITMs:

AbrasionAASHTO T 96

*Amount of Material finer than

No. 200 (75 Fm) SieveAASHTO T 11

Brine Freeze-and-Thaw Soundness ITM 209

Clay Lumps and Friable Particles..... AASHTO T 112

Control Procedures for Classification of Aggregates..... ITM 203

Crushed Particles..... ITM 204

	Dolomite Aggregates	ITM 205
	Freeze-and-Thaw Beam Expansion	ITM 210
	*Lightweight Pieces in Aggregates	AASHTO T 113
	*Sampling Aggregates	AASHTO T 2
	Sampling Stockpiled Aggregates	ITM 207
	Scratch Hardness.....	ITM 206
	*Sieve Analysis.....	AASHTO T 27
	*Soundness	AASHTO T 103, T 104
	*Specific Gravity and Absorption.....	AASHTO T 85
320	Unit Weight and Voids in Aggregates	AASHTO T 19
	*Except as noted in 904.03.	

904.03 Exceptions to AASHTO Standard Methods.

(a) Exceptions to AASHTO T 2. Stockpile sampling shall be done in accordance with ITM 207, unless otherwise permitted.

(b) Exceptions to AASHTO T 11, T 27, and T 37.

- 330
1. When tests are performed in the field where ovens are not available, test samples may be dried in suitable containers over open flame or electric hot plates with sufficient stirring to prevent overheating, then cooled to constant mass (weight).
 2. The scales used for performing field tests of fine aggregates shall be graduated in increments not greater than one gram.

(c) Exceptions to AASHTO T 27 for Coarse Aggregates.

340 The size of test samples for coarse aggregate shall be as follows:

Aggregate Size	Minimum Mass (Weight) of Test Sample
No. 1.....	68-90.7 kg (150-200 lb)
No. 2.....	11.3 kg (25 lb)
No. 5, 8, 53, and 91	6-8 kg
No. 9 and 11.....	4-6 kg
*Subbase	4-6 kg
*B Borrow.....	4-6 kg

350

* If subbase or B borrow is fine aggregate, at least 90% passing the 4.75 mm (No. 4) sieve, the test sample shall be approximately 500 grams.

(d) Blank.

(e) Exceptions to AASHTO T 103 and T 104.

- 360
1. Counting the number of individual particles coarser than the 19.0 mm (3/4 in.) sieve will not be required.
 2. For testing ledge rock, the ledge samples shall be crushed to obtain test samples for the designated increments passing the 37.5 mm (1 1/2 in.) sieve and retained on the 4.75 mm (No. 4) sieve. The factors used to calculate the weighted average loss are 30%, 40% and 30% of the 37.5 mm (1 1/2 in.) - 19.0 mm (3/4 in.), 19.0 mm (3/4 in.) - 9.5 mm (3/8), and 9.5 mm (3/8) - 4.75 mm (No. 4) increments, respectively.
- 370
3. In the case of ledge rock, modify sections 3.3 and 6.2 of T 103 and T 104 respectively. When the sample received is deficient in material of a component size of any test portion, that material will be supplemented with the available component size to provide the test portion.
 4. Modify section 8 of T 103 and section 10 of T 104. For materials designated as a coarse aggregate, the weighted loss will be calculated considering the material retained on the 4.75 mm (No. 4) sieve as 100% of the sample, and only the total weighted loss reported. In AASHTO T 104 sections 10.1.3.2 and 10.1.3.3 shall not apply, and unless otherwise noted only new solution will be used.
- 380

(f) Exceptions to AASHTO T 85. The in-water mass shall be determined following the 15 h soaking period prior to determining the saturated surface dry mass (weight).

904.04 Riprap. Riprap aggregate shall consist of sound stone, stone masonry, steel slag for dumped riprap only, or other approved material, free from structural defects and of approved quality. Stone containing shale, unsound sandstone, or other material which will disintegrate readily, shall not be used.

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(a) Dumped Riprap. Dumped riprap shall be broken concrete, masonry, or stone removed from an old structure; broken pieces removed from concrete pavement, base, or monolithic brick pavement; or broken rock from class X, class Y, unclassified excavation, or solid rock excavation. Material provided from sources outside the right-of-way shall be coarse aggregate, class F or higher.

400 **(b) Revetment, Class 1, and Class 2 Riprap.** The material shall be coarse aggregate, class F or higher. It shall be in accordance with the following requirements and such that the maximum dimension of individual pieces shall not be greater than three times the minimum dimension.

GRADATION REQUIREMENTS			
Percent smaller			
Size, mm (in.)	Revetment	Class 1	Class 2
750 (30)			100
600 (24)		100	85-100
450 (18)	100	85-100	60-80
300 (12)	90-100	35-50	20-40
150 (6)	20-40	10-30	0-20
75 (3)	0-10	0-10	0-10
Depth of Riprap, minimum	450 mm (18 in.)	600 mm (24 in.)	750 mm (30 in.)

Each loading shall have a similar gradation. The riprap will be visually inspected for size and shape.

410 **(c) Grouted Riprap.** Grouted riprap material shall be in accordance with 904.04(a) or revetment riprap. The mortar shall be composed of one part cement in accordance with 901.01(b) and four parts No. 23 fine aggregate in accordance with 904.01. The cement and fine aggregate shall be dry-mixed to a uniform mixture. Water in accordance with 913.01 shall be added as the mixing continues until the grout attains a consistency which will allow it to flow into the openings.

(d) Uniform Riprap. The material shall be coarse aggregate, class F or higher. Uniform riprap shall have a 200 mm (8 in.) top size, not more than 20% of the material passing the 25 mm (1 in.) sieve, and a well-graded gradation between the 200 mm (8 in.) and 25 mm (1 in.) sieves to produce a uniformly dense surface.

420 **(e) Precast Cement Concrete Riprap.** Precast concrete riprap shall consist of unreinforced concrete units of the thickness specified and shall be in accordance with the details shown on the plans. The precast concrete units shall be in accordance with ASTM C 139 except aggregates shall be in accordance with 904.01(a) for the fine aggregates and 904.02, class A, for the coarse aggregates. The minimum compressive strength shall be 17 MPa (2500 psi) for an average of three units and 16 MPa (2300 psi) for individual units. The maximum water absorption shall be 190 kg/m³ (12 lb/cu ft) for an average of three units.

SECTION 905 – MASONRY UNITS

905.01 Clay or Shale Brick. Brick shall be in accordance with the following specifications.

(a) Sewer Brick. Sewer brick shall be in accordance with AASHTO M 91.

(b) Manhole Brick. Manhole brick shall be in accordance with AASHTO M 91.

(c) Building Brick. Building brick shall be in accordance with AASHTO M 114, Grade SW.

905.02 Concrete Brick. Concrete brick intended for use in construction of manholes, catch basins, and similar structures, or as building bricks, shall be in accordance with ASTM C 55, Grade S-II.

905.03 Concrete Masonry Blocks. Concrete masonry blocks may be rectangular or segmented and, when specified, shall have ends shaped to provide interlock at vertical joints. Solid masonry units shall be in accordance with ASTM C 139. Hollow load-bearing masonry units shall be in accordance with ASTM C 90, Grade N-II.

SECTION 906 – JOINT MATERIALS

906.01 Joint Fillers. Joint fillers shall be preformed materials intended to be used in cement concrete pavement and bridge joints or as otherwise specified. Joint fillers shall be in accordance with AASHTO M 153, or AASHTO M 213. However, the asphalt content will be determined by ITM 801, rather than by AASHTO T 42.

906.02 Joint Sealing Materials.

(a) Joint Sealers. Joint sealers shall consist of materials which are intended to be used in sealing joints and cracks in pavements and structures.

1. Silicone Joint Sealants.

a. Physical Requirements. Silicone joint sealants shall be in accordance with ASTM D 5893.

b. Field Evaluation. All silicone joint sealants complying with the physical requirements will be subjected to a field evaluation before approval for general use is granted. The Department will maintain a List of the Joint Sealants which comply with the physical requirements and field evaluation.

c. Specific Requirements for Installation of Silicone Joint Sealant.

The sealant shall be stored in the original unopened container at or below 32EC (90EF). The sealant shall be placed when the ambient temperature is above 4EC (40EF). The equipment used shall be adequate for the placement of the sealant and shall meet the sealant manufacturer's recommendations. Air compressors used for the placement of this sealant shall be equipped with traps which remove moisture and oil from the air.

30 The approved sealants which are self leveling shall be identified as such on the Approved List of Joint Sealants and will not require tooling. Sealants not identified as self leveling on the approved list shall be tooled or applied in such a manner which causes them to wet the joint faces. Such sealants which are not formulated for self leveling will not position properly in the joint under its own mass (weight). A backer rod as set out herein shall be used to control sealant configuration and facilitate tooling. Applicable joint configurations shall be as shown on the plans. After a joint has been sealed, all surplus joint sealer on the pavement surfaces shall be promptly removed. Traffic shall not be permitted over sealed joints until the sealer is tack free.

40 The sealant shall be delivered in containers plainly marked with manufacturer's name or trade mark.

2. Hot Poured Joint Sealant.

a. General Requirements. The sealant shall be in accordance with AASHTO M 301. The material shall be tested in accordance with ASTM D 3407 except that after blotting, the surface of the blocks shall be blown surface dry with compressed air.

50 **b. Packaging and Marking.** The sealing compound shall be delivered in the manufacturer's original sealed container. Each container shall be legibly marked with the name of the manufacturer, the trade name of the sealer, the manufacturing batch number or lot, the pouring temperature, and the safe heating temperature.

c. Requirements for Installation. The sealant shall be used in accordance with the manufacturer's recommendations. A backer rod as set out herein shall be used to provide the joint configuration in accordance with the standard drawings.

60 **d. Sampling and Testing.** Samples may be taken prior to delivery provided the plant or warehouse is located in the geographical area serviced by the Department's inspectors. If not sampled prior to delivery, it will be sampled at the job site. Scheduling shall provide two weeks, after delivery to the Division of Materials and Tests for testing. The basis of use will be the applicable laboratory number.

3. Preformed Elastomeric Joint Seals. This joint seal shall be in accordance with AASHTO M 220. Joint seals furnished under this specification shall be covered by a type A certification in accordance with 916. Sampling of joint seals in accordance with AASHTO M 220 will be required. The lubricant-adhesive shall be covered by a type C certification in accordance with 916.

(b) Backer Rod. The rod is to act as a bond breaker, to control the thickness of the bead, and to provide support for any required tooling of the sealant.

1. Requirements. When hot poured material is used, compatibility of the backer rod with the hot sealant shall be verified before use. The backer rod shall be a closed cell expanded polyethylene foam or an isomeric polymer foam rod. Diameter and placement shall be as shown on the plans.

2. Certification. Backer rod furnished under this specification shall be covered by a type C certification in accordance with 916.

906.03 Joint Mortar. Pipe joint mortar shall consist of one part portland cement and two parts sand with water as necessary to obtain the required consistency. Mortar shall be used within 30 min after its preparation.

906.04 Rubber Type Gaskets. Ring gaskets for pipe shall be in accordance with AASHTO M 198, type A. Material furnished under this specification shall be covered by a type B certification in accordance with 916.

906.05 Bituminous Mastic Pipe Joint Sealer. This is a cold applied, mineral filled, joint sealing compound for joints of bell and spigot or tongue and groove concrete or clay pipe. It shall be a steam refined petroleum asphalt, plasticized to a homogeneous consistency with mineral fillers.

(a) General Requirements. This sealer shall be a smooth uniform mixture, not thickened or livered, and shall show no separation which cannot be overcome easily by stirring. The material shall be of such consistency and proportions that it can be applied readily with a trowel, putty knife, or caulking gun without pulling or drawing. It shall exhibit good adhesive and cohesive properties when applied to metal, concrete, or vitrified clay surfaces. It shall not be damaged by exposure to below freezing temperatures and shall be applicable when the temperature of the air is between -7EC (20EF) and 38EC (100EF).

(b) Detail Requirements.

1. When applied in a layer 1 mm (1/16 in.) to 3 mm (1/8 in.) thick on a tinned metal panel and cured at room temperature for 24 h, the bituminous mastic pipe joint sealer shall set to a tough plastic coating free from blisters.

- | | Min. | Max. |
|--|------|------|
| 2. Grease cone penetration unworked, 150 g, 25EC, 5 s, ASTM D 217, mm/10 | 125 | 225 |

- 120
3. Non-Volatile, 10 g, 105EC-110EC, 24 h, % 75
 4. Ash, by ignition, %..... 15 45
 5. Flash Point (ASTM D 92), EC (EF).....38 (100)
 6. Fire Point (ASTM D 92), EC (EF).....66 (150)
 7. Cold Temperature Flexibility @ -12EC (10EF)**C**shall not crack.
Test: Trowel joint mastic approximately 6 mm (1/4 in.) thick on heavy kraft paper or very light gage sheet metal. Condition in a freezer at -12EC (10EF) for 3 h. Bend the sample over a 25 mm (1 in.) diameter pin or mandrel.
 8. High Temperature Resistance @ 60EC (140EF), 10 h**C**no sag. Test: Trowel joint mastic approximately 12.5 mm (1/2 in.) thick on a porous concrete slab or piece of concrete block. Place in oven at 60EC (140EF) for 10 h.

130 **(c) Certification.** Material furnished under this specification shall be covered by a type C certification in accordance with 916.

906.05.1 Joint Membrane System for Precast Reinforced Concrete Box Sections. The Contractor may elect to use an approved self-adhering membrane system in lieu of the detail shown on the plans.

Approved membrane systems shall be in accordance with the following requirements.

	PROPERTY	TEST METHOD	REQUIREMENT
140	Thickness	ASTM D 3767 Procedure A	1.5 mm Min.
	Tensile Strength	Grab Tensile Strength, ASTM D 4632	650 N Min.
	Elongation	Grab Tensile Strength, ASTM D 4632	20% Min.
150	Bursting Strength	Mullen Burst, ASTM D 3786	2.0 MPa Min.
	Peel Strength	ASTM D 903	850 N/m Min.
	Permeance	ASTM E 96, Water Method	60 ng/m ² s Pa Max.

160 The membrane system shall be supplied in roll widths of at least 300 mm (12 in.). The membrane shall be a composite sheet material composed of a non-woven fabric and a polymer membrane material. The membrane shall be protected by a release paper. The alternate membrane systems to be used shall be selected from the List of Approved Membrane Systems for Precast Reinforced Concrete Box Sections.

Requests for adding membrane systems to the approved list must be supported by a type B certification documenting compliance with the above requirements and a sample. The certification shall be prepared by the manufacturer in accordance with the applicable requirements of 916. No relabeled materials will be considered for approval. A specified material on the approved list will not be listed under more than one name.

170 When a product is determined to be acceptable, it will be added to the approved list and it may be used upon publication of the list.

906.06 Bridge Expansion Joints.

(a) Type SS. Structural steel shall be in accordance with ASTM A 36M (ASTM A 36), A 588M (A 588), A 570M (A 570), A 242M (A 242), or Merchant Quality 1010, 1020.

180 Sealant and grouts shall be in accordance with Federal Specifications TT-S-00230 or as recommended by the manufacturer.

The elastomer shall be neoprene in accordance with ASTM D 3542 except that the physical requirements in Table 1 for low temperature recovery, high temperature recovery, and compression-deflection properties will not apply.

The structural steel and polyurethane sealant shall be covered by a type C certification, and the elastomer shall be covered by a type B certification, both in accordance with 916.

(b) Type BS2, BS6, BS8, BS9, BS11, and 1-A. Materials shall be in accordance with ASTM D 3542. The dimension and tolerance requirements shall be as specified in the following table for the type or types of joints specified.

EXPANSION JOINT TYPE	SEAL WIDTH	SEAL HEIGHT	JOINT WIDTH @ INSTALLATION
BS2	41 mm (1 5/8 in.) " 3 mm (" 1/8 in.)	41 mm (1 5/8 in.) " 3 mm (" 1/8 in.)	22 mm (7/8 in.) + 3 mm, - 6 mm (+ 1/8 in., - 1/4 in.)
BS6	64 mm (2 1/2 in.) - 0, + 6 mm (- 0, + 1/4 in.)	64 mm (2 1/2 in.) + 10 mm, - 3 mm (+ 3/8, - 1/8 in.)	38 mm (1 1/2 in.) + 3 mm, - 6 mm (+ 1/8 in., - 1/4 in.)
BS8	76 mm (3 in.) - 0, + 6 mm (- 0, + 1/4 in.)	83 mm (3 1/4 in.) " 6 mm (" 1/4 in.)	48 mm (1 7/8 in.) + 3 mm, - 6 mm (+ 1/8 in., 1/4 in.)
BS9	100 mm (4 in.) - 0, + 6 mm (- 0, + 1/4 in.)	111 mm (4 3/8 in.) " 10 mm (" 3/8 in.)	64 mm (2 1/2 in.) + 3 mm, - 6 mm (+ 1/8 in., - 1/4 in.)
BS11	127 mm (5 in.) - 0, + 6 mm (- 0, + 1/4 in.)	128 mm (5 1/8 in.) " 6 mm (" 1/4 in.)	75 mm (3 in.) + 3 mm, - 6 mm (+ 1/8 in., - 1/4 in.)
1-A	16 mm (5/8 in.) " 2 mm (" 1/16 in.)	17 mm (11/16 in.) " 3 mm (" 1/8 in.)	6 mm (1/4 in.) - 0, + 3 mm (- 0, + 1/8 in.)

The material shall be covered by a type A certification in accordance with 916 and sampling of the material will be required. Satisfactory test results shall be obtained from the samples prior to the installation of the seal. The lubricant-adhesive shall be covered by a type C certification in accordance with 916.

(c) Type M Structural steel shall be in accordance with ASTM A 36M (A 36), A 570M (A 570), A 242M (A 242), A 588M (A 588), or Merchant Quality 1010, 1020.

Sealant and grouts shall be in accordance with Federal Specification TT-S-00230 or as recommended by the joint manufacturer.

Elastomer shall be neoprene in accordance with ASTM D 3542.

The structural steel and sealant shall be covered by a type C certification and the elastomer by a type B certification, both in accordance with 916.

210

Bearings above and below the support bar shall be a nylon or urethane compound with polytetrafluorethylene riding surfaces. All components of the system shall be accessible to periodic inspection and component replacement if necessary.

The elastomeric seals shall be in accordance with the requirements as follows:

220

1. be supplied and installed in one piece;
2. have corner locked edges for a watertight fit;
3. not be any part of the load bearing riding surface;
4. be installed using seal lubricant-adhesive or be mechanically clamped in position to produce a watertight seal;
5. have a shape which promotes self removal of foreign material during normal joint operation;
6. be recessed 13 mm (1/2 in.) below the riding surface throughout the normal limits of joint movement;
7. be held in position by the separator beams;
8. have a hollow box shape for joints utilizing urethane equilibrium control spacers or a strip seal configuration for joints using a mechanical linkage to maintain equidistant separator beam spacing.

230

The separator beams shall be in accordance with the requirements as follows:

240

1. provide the riding surface across the joint;
2. have an extruded or machined shape suitable to hold the seals;
3. be stable against tipping, tilting, or lifting during application of traffic loads by use of a suitable shape and connection to the support bar;
4. be supported individually on their own independent support bars;
5. maintain equidistant spacing through use of suitable urethane equilibrium type control spacers or through a positive horizontal mechanical linkage or proportioning bar.

250

The support bars shall be in accordance with the requirements as follows:

1. incorporate stainless sliding surfaces to minimize resistance to joint movements;
2. be supported above, below, and laterally as required to prevent lifting, to transmit bearing loads, and to maintain positioning of the bar.

All support bar boxes and joint housings shall have top, bottom, and sides made of steel plate with 13 mm (1/2 in.) minimum thickness. Anchorages shall consist of looped No. 5 reinforcing bars welded to 13 mm (1/2 in.) steel plates spaced at 230 mm (9 in.) centers. No unwelded steel to steel contact will be permitted.

SECTION 907 – CONCRETE, CLAY, AND PLASTIC DRAINAGE COMPONENTS

907.01 Non-Reinforced Concrete Pipe. This pipe shall be in accordance with AASHTO M 86M (M 86) for the specified diameter and strength classes. When used for underdrain, each section of pipe shall not exceed 0.9 m (3 ft) in length.

907.02 Reinforced Concrete Pipe. This pipe shall be in accordance with AASHTO M 170M (M 170) for the specified diameters and strength classes. Unless otherwise specified, pipe wall design and use of elliptical reinforcement in circular pipe are optional.

When the pipe listed below is specified or permitted, it shall be in accordance with the class noted.

Extra Strength Reinforced Concrete Pipe	Class IV
Heavy Duty Reinforced Concrete Pipe	Class V
Reinforced Concrete Pipe	Class III
Reinforced Concrete Sewer Pipe.....	Class II

Precast reinforced concrete end sections shall be in accordance with the cited specifications to the extent to which they apply.

The manufacturer of the steel reinforcement shall furnish to the pipe manufacturer a mill test report. The pipe manufacturer shall certify, on furnished forms that:

- (a) The pipe has been manufactured in accordance with these Standard Specifications.
- (b) The area of the steel reinforcement per meter (linear foot) of pipe is in accordance with or exceeds the specification requirements.

(c) Based on the steel reinforcement manufacturer's mill test report, the steel used in the pipe is in accordance with the specification requirements.

(d) Copies of the steel reinforcement manufacturer's mill test reports shall be on file and available to review for five years.

40 **907.03 Reinforced Concrete Horizontal Elliptical Pipe.** This pipe shall be in accordance with AASHTO M 207M (M 207). Certification shall be in accordance with 907.02.

907.04 Precast Concrete Manholes, Inlets, and Catch Basins. These units shall be in accordance with AASHTO M 199M (M 199). References to diameter are applicable to corresponding dimensions in other than circular sections. Absorption tests will not be required for flat top or base slabs. Certification shall be in accordance with 907.02.

50 No more than three holes shall be cast or drilled in each section for the purpose of handling.

 In addition to the requirements of AASHTO M 199M (M 199), the manhole steps shall be permanently marked with the specific step designation, and the manufacturer's identification. This marking shall remain exposed after installation.

 Steps shall be selected from the list of approved manhole steps. Requests for adding steps to the list shall be accompanied by: a certified test report demonstrating compliance with AASHTO M 199M (M 199); instruction for proper installation; complete product description including the ancillary equipment required for installation; and a sample step. The Department may perform a laboratory evaluation of specific steps and may not add steps to the list which are not furnished with ancillary installation equipment.

60 **907.05 Precast Reinforced Concrete Box Sections.** Box sections with 0.6 m (2 ft) of cover or greater shall be in accordance with AASHTO M 259M (M 259) and box sections with less than 0.6 m (2 ft) of cover which are subject to highway loadings shall be in accordance with AASHTO M 273M (M 273). Box sections furnished in accordance with AASHTO M 259M (M 259) or AASHTO M 273M (M 273) shall have a minimum 28 day compressive strength of 34.5 MPa (5,000 psi), as determined by concrete cores. Certification shall be in accordance with 907.02.

70 Not more than four holes may be cast, drilled, or otherwise neatly made in the shell of each piece of box section for the purpose of handling or laying. The holes shall be tapered unless drilled, and the tapered holes shall be filled with portland cement mortar or with precast concrete plugs, which shall be secured with portland cement mortar or other approved adhesive, before backfilling. Drilled holes shall be filled with portland cement mortar.

907.06 Blank.**907.07 Blank.**

907.08 Clay Pipe. This pipe shall be in accordance with AASHTO M 65 for the specified diameters and strength classes for circular unperforated pipe. When specified, the bell shall have integral spacer lugs to provide for an annular opening and self centering feature. The pipe may be glazed or unglazed, unless otherwise specified.

90 **907.09 Perforated Clay Pipe.** This pipe shall be in accordance with AASHTO M 65 for the specified dimensions and strength classes. It may be glazed or unglazed, unless otherwise specified. Where vitrified clay culvert pipe is furnished, a pipe end section compatible to that as required for concrete or metal pipe shall be used.

907.10 Blank.

100 **907.11 Drain Tile.** This pipe shall be in accordance with AASHTO M 178M (M 178) for concrete or M 179 for clay for the specified material, diameters, and quality classes. Standard quality drain tile shall not be used. When specified, the pipe spigot shall have integral spacer lugs to provide for an annular opening and self centering feature.

907.12 Blank.**907.13 Blank.****907.14 Blank.****907.15 Blank.**

110 **907.16 Plastic Pipe Manufacturer Requirements.** An approved List of Plastic Pipe, Fittings, Solvent Cement, and Elastomeric Seals will be maintained by the Department. The list will specify the manufacturer, plastic pipe, solvent cement, or elastomeric seals designation. All of these materials shall comply with the applicable AASHTO or ASTM requirements and will only be accepted from qualified manufacturers. The manufacturer is defined as the plant which produces the plastic pipe, fittings, solvent cements, or elastomeric seals. The manufacturer shall become qualified by establishing a history of satisfactory quality control of these materials as evidenced by the test results performed by the manufacturer's testing laboratory.

120 Manufacturers requesting to be qualified to supply plastic pipe, solvent cements, or elastomeric seals shall submit the following to the Materials and Tests Division.

- (a) a quality control plan which encompasses all aspects of the production process starting with the raw materials and concluding with the shipment of the finished product. The quality control plan shall provide for a 95% or greater statistical assurance that the materials will be in accordance with the specifications, and include type and frequency of sampling and testing;
- 130 (b) documentation indicating that the manufacturer's testing laboratory is in accordance with the provisions of AASHTO R 18;
- (c) a monthly summary of all test results for the previous 12 months production for each type of plastic pipe, fittings, solvent cements and elastomeric seals;
- (d) a material safety data sheet for each material produced; and
- 140 (e) To maintain qualification, the manufacturer shall submit to the Materials and Tests Division a monthly summary of all tests for each type of pipe, pipe fittings, solvent cement, and elastomeric seals produced. If a specific type of pipe, pipe fitting, solvent cement, or elastomeric seals is not manufactured in a given month, the monthly submittal shall state: No type ____ pipe, pipe fitting, solvent cement, or elastomeric seals was manufactured during the month of _____ 19____.

The manufacturer shall provide the type of certification specified in the Frequency Manual and in accordance with 916 which designates that hydrostatic design basis, HDB, rated resins or non-HDB rated resins were used in the manufacture of the pipe and fittings.

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907.17 Corrugated Polyethylene Drainage Tubing. Tubing and fittings shall be in accordance with AASHTO M 252. Perforations shall be required for tubing used as a longitudinal underdrain. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.18 Perforated Polyvinyl Chloride Semicircular Pipe. Perforated polyvinyl chloride semicircular pipe may be used as an alternate to 150 mm (6 in.) or less diameter pipe or tile. Pipe shall be in accordance with ASTM D 3034, SDR 35. This semicircular pipe shall have a smooth top and a smooth, semicircular bottom, nominally 118 mm (4 5/8 in.) in diameter, with perforations uniformly distributed along the top of the bottom section in accordance with AASHTO M 252 perforation requirements. The top section shall extend a minimum of 13 mm (1/2 in.) beyond the top of the semicircular section. The top section shall be approximately 162 mm (6 3/8 in.) wide including the sloping overhangs on each side. Qualification requirements for the manufacturers shall be in accordance with 907.16.

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907.19 Corrugated Polyethylene Pipe. Pipe and fittings shall be in accordance with AASHTO M 294. The compound used in manufacturing this pipe shall have a minimum cell class in accordance with 335420C as shown in ASTM D 3350. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.20 Ribbed Polyethylene Pipe. Pipe and fittings shall be in accordance with ASTM F 894 for the specified sizes. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.21 Smooth Wall Polyethylene Pipe. Pipe shall be in accordance with ASTM F 714 for nominal diameters of 1000 mm (39 in.) or less. Fittings shall be in accordance with ASTM F 1055. The pipe sizes shall be in accordance with ISO sizing system. The pipe dimension ratio shall be 26 or less. The compound used in manufacturing this type of pipe shall have a minimum cell class in accordance with 335434C as shown in ASTM D 3350. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.22 Profile Wall Polyvinyl Chloride Pipe. Pipe and fittings shall be in accordance with AASHTO M 304 for nominal diameters of 900 mm (36 in.) or less. Perforations shall be required when used as a longitudinal underdrain. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.23 Smooth Wall Polyvinyl Chloride Pipe. Pipe and fittings shall be in accordance with AASHTO M 278 for pipe sizes 100 mm through 375 mm (4 in. through 15 in.), and ASTM F 679 for pipe sizes 450 mm through 675 mm (18 in. through 27 in.). The compound used in manufacturing pipe shall have a minimum cell class in accordance with 12454C as shown in ASTM D 1784. Qualification requirements for the manufacturers shall be in accordance with 907.16.

907.24 Smooth Wall Pipe for Outlets. Pipe and pipe fittings shall be smooth wall, non-perforated plastic pipe. Qualification requirements for the manufacturers of the following materials shall be in accordance with 907.16.

(a) Type PSM Polyvinyl Chloride Pipe and Fittings. Pipe and fittings shall be in accordance with ASTM D 3034, SDR 23.5.

(b) Schedule 40 Polyvinyl Chloride Pipe. Pipe shall be in accordance with ASTM D 1785 and shall have a minimum pipe stiffness of 1030 kPa (150 psi) at 5% deflection when determined in accordance with ASTM D 2412.

907.25 Solvent Cements for Polyvinyl Chloride Pipe and Pipe Fittings. Solvent cement for polyvinyl chloride pipe and fittings shall be in accordance with ASTM D 2564. Qualification requirements for the manufacturers of this material shall be in accordance with 907.16.

907.26 Elastomeric Seals. Elastomeric seals for joining plastic pipe shall be in accordance with ASTM F 477. Qualification requirements for the manufacturers of this material shall be in accordance with 907.16.

SECTION 908 – METAL PIPE

908.01 Blank.

10 **908.02 Corrugated Steel Pipe and Pipe-Arches.** This pipe or pipe-arch and the coupling bands shall be zinc coated steel or aluminum coated steel in accordance with AASHTO M 36M (M 36), except as noted herein. They may be fabricated with circumferential corrugations and riveted lap joint construction or with helical corrugations with continuous lock or welded seam extending from end to end of each length of pipe. Reforming the ends of helical corrugated pipe to form circumferential corrugations will be permitted to allow use of circumferential corrugated coupling bands. The reforming shall be limited to the length required to accommodate the coupling bands and in such a manner that there is no appreciable slippage of the seam nor a plane of weakness created.

The pipe shall be Type I, IA, II, or IIA.

20 Band couplers shall have corrugations that mesh with the corrugations of the pipes.

Fittings, including stub-tee connections and saddle connectors specified in 715.06, shall be shop fabricated. Damage to the coating on fittings shall be repaired in accordance with AASHTO M 36.

If the pipe or pipe-arch invert is to be paved, it shall first be coated over half its circumference in accordance with 908.07. The paved invert shall then be constructed in accordance with 908.07.

30 Sheet metal used to fabricate pipe shall be the same brand from the same manufacturer in any one length of finished pipe.

The manufacturer shall furnish to the fabricator a certified mill report for materials shipped to the fabricator. This certified mill report shall list the kind of base metal, actual test results of the chemical analysis and mechanical tests of each heat, the thickness, the mass (weight) of coating, and shall certify that the material complies with specified requirements for the type of metal furnished.

The fabricator shall certify, on furnished forms that:

- 40 (a) the fabricated structure has been manufactured in accordance with these Standard Specifications;
- (b) based on the sheet manufacturer's certified mill report, the materials used in fabricating the structure were tested and the test results are in accordance with the specified requirements; and

- (c) Copies of the sheet manufacturer's certified mill report shall be on file and available to review for five years.

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908.03 Blank.

908.04 Corrugated Aluminum Alloy Pipe and Pipe-Arches. Pipes, pipe-arches, and coupling bands shall be in accordance with AASHTO M 196M (M 196). The pipe shall be Type I, IA, II, or IIA. If the pipe invert is to be paved, it shall be in accordance with 908.07.

The sheet manufacturer's certified mill report and the fabricator's certification shall be in accordance with 908.02, except the documents shall be in accordance with the applicable requirements of AASHTO M 196M (M 196).

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Where aluminum alloy pipe culvert is furnished, aluminum alloy end sections shall also be furnished. All component parts shall be aluminum alloy.

908.05 Blank.

908.06 Metal End Sections. The end section's metal shall be in accordance with AASHTO M 36M (M 36) or M 196M (M 196), whichever is applicable. The sheet metal manufacturer's certified mill report and the fabricator's certification shall be in accordance with 908.02 or 908.04, whichever is applicable.

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End sections consisting of multiple panels shall have lap seams which shall be tightly jointed with M10 (3/8 in.) galvanized rivets or bolts.

All steel pipe end sections shall have a toe plate anchor constructed of 3.5 mm (0.138 in.) thick galvanized steel. The toe plate anchor shall be match punched to fit holes in the skirt lip, and shall be supplied loose, and complete with M10 (3/8 in.) diameter galvanized bolts.

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Straps for pipe end sections shall be either galvanized 20M (No. 6) reinforcing bars or zinc coated 10 mm (3/8 in.) diameter aircraft cable.

908.07 Fiber Bonded Fully Bituminous Coated Corrugated Steel Culvert Pipe and Pipe-Arches. The material, fabrication, the manufacturer's certified mill report, and fabricator's certification shall be in accordance with the applicable requirements of 908.02. The fiber bonding requirements shall be as described herein. Coupling bands shall be fiber bonded fully bituminous coated.

90 The fibers used in the bonding process shall be aramid. The fibers shall be applied evenly in sheet form on both sides of the steel sheet by embedding them into a molten zinc bonding medium. Immediately after solidification of the zinc bonding medium, the fibers shall be thoroughly impregnated with an asphalt saturant. The finished steel sheets shall be free from blisters and unsaturated areas. The steel sheets shall then be corrugated and fabricated into culvert. After fabrication, the pipe or pipe-arch shall be fully bituminous coated.

Connecting or coupling bands shall be of the 2-piece type when used with coated pipe of 900 mm (36 in.) diameter or larger.

100 The asphalt material for coating shall be in accordance with 902.02. Samples of the asphalt material will be obtained from the working tank prior to or during coating of the pipe, or from strippings off the pipe after coating. When applied to the pipe, the asphalt material shall be free from impurities. The metal shall be free from grease, dust, or moisture. Either process set out below may be used for application.

- (a) When the pipe is not preheated, the temperature of the asphalt at the time of immersion shall be 204EC " 3EC (400EF " 5EF). The duration of the immersion in the asphalt shall be in accordance with the following:

Thickness (inches)	1.32 mm	1.63 mm	2.01 mm	2.77 mm	3.51 mm	4.27 mm
	(0.052 in.)	(0.064 in.)	(0.079 in.)	(0.109 in.)	(0.138 in.)	(0.168 in.)
Minimum Immersion Time for first Dip (min)	2.0	2.5	3.0	5.0	6.5	8.0

- 110 (b) When the pipe is preheated it shall be brought to a temperature of 149EC (300EF) and the asphalt shall be heated to a temperature of 193EC " 3EC (380EF " 5EF) before the pipe is dipped.

In either process, the pipe shall be dipped a second time or more if necessary, to give a minimum thickness of 1.3 mm (0.05 in.).

120 If paved invert is specified, the pipe or pipe-arch shall first be fully coated as required. Additional bituminous material shall be applied in the bottom section to form a smooth pavement. Except where the upper edges intersect the corrugations, the pavement shall have a minimum thickness of 3 mm (1/8 in.) above the crests of the corrugations. The pavement shall be applied to the lower quarter of the circumference.

The manufacturer of the asphalt material shall furnish to the pipe fabricator the type of certification specified in the Frequency Manual and in accordance with 916 for each shipment or lot of asphalt material. The pipe fabricator shall keep these certifications on file and available to review for five years. In addition, samples from the working tank will be obtained for verification of requirements.

908.08 Polymer Precoated Galvanized Corrugated Steel Culvert Pipe and Pipe-Arches. The pipe or pipe-arch and coupling bands shall be in accordance with AASHTO M 245M (M 245) with additions in accordance with 908.02. The polymer precoated galvanized steel sheets shall be in accordance with AASHTO M 246M (M 246), Grade 250/250 (10/10).

908.09 Structural Plate Pipe, Pipe-Arches, and Arches.

(a) Steel. Steel structural plate pipe, pipe-arches, and arches shall be constructed from individually galvanized corrugated steel plates as described herein. For pipes and pipe-arches having a thickness less than 7.11 mm (0.280 in.), the bottom plates shall be of the next greater thickness than that specified for the top and side plates, not including corner plates for pipe-arches. The individual plates shall be in accordance with AASHTO M 167M (M 167) and Section 26 of the AASHTO Standard Specifications for Highway Bridges, Division II.

The materials and fabrication shall be as follows:

1. The minimum corner plate radius of the arc joining the top and bottom plates of pipe-arches shall be 457 mm (18 in.) for openings up to and including 12.2 m² (131 sq ft) and 787 mm (31 in.) for openings over 12.2 m² (131 sq ft). The minimum radius of the arc shall be 787 mm (31 in.) for openings from 9.1 m² (98 sq ft) up to and including 19.8 m² (214 sq ft).
2. Assembly bolts shall be in accordance with AASHTO M 164M (M 164), ASTM A 325M (A 325), or ASTM A 449. Nuts shall be in accordance with ASTM A 563M (A 563), class 8S (grade C); AASHTO M 164M (M 164); or ASTM A 325M (A 325). Assembly bolts, nuts, and washers shall be galvanized in accordance with ASTM A 153, or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153, class C.
3. The sheet manufacturer's certified mill report and the fabricator's certification shall be furnished in accordance with 908.02, except the documents shall be in accordance with the applicable requirements of AASHTO M 167M (M 167).

(b) Aluminum Alloy. Aluminum alloy structural plate pipe, pipe-arches, and arches shall be in accordance with AASHTO M 219M (M 219). The sheet manufacturer's certified mill report and the fabricator's certification shall be furnished in accordance with 908.02.

908.10 Cast Iron Soil Pipe. This pipe shall be in accordance with ASTM A 74. Markings shall be in accordance with ASTM A 74 or ANSI A 40.1.

908.11 Steel Pipe. This item shall be electric-fusion, arc-welded steel pipe in accordance with ASTM A 139, grade B, or electric-resistance welded pipe in accordance with ASTM A 53, Type E, Grade B, as applicable. Material furnished under this specification shall be covered by the type of certification specified in the Frequency Manual and in accordance with 916.

908.12 Straps, Hook Bolts and Nuts Used in Anchors. Straps shall be of the type and size shown on the plans. Reinforcing bars used for straps shall meet the applicable requirements of 910.01 and shall be galvanized in accordance with ASTM A 767M (A 767), class I. Aircraft cable used for straps shall be made of zinc coated steel wire, 9.5 mm (3/8 in.) nominal diameter, consisting of seven 19 wire flexible steel strands, with a minimum breaking strength of 62.3 kN (14,000 lb). The cable shall be in accordance with Military Specification MIL-W-1511.

Hook bolts and nuts shall be of the size shown on the plans, shall be in accordance with the applicable requirements of ASTM A 307, and shall be galvanized in accordance with ASTM A 153. Threads shall be American Standard Coarse Thread Series Class 2 fit. Threads shall be cleaned after galvanizing to provide a free running fit. Maximum oversizing of the nut threads shall be 0.4 mm (1/64 in.).

908.13 Fully Bituminous Coated and Lined Corrugated Steel Pipe and Pipe-Arches. The material, fabrication, bituminous coating, and 100% paving shall be in accordance with the applicable requirements of 908.02 and 908.07. Coupling bands shall be fully bituminous coated.

908.14 Slotted Drain or Slotted Vane Drain Pipe. Slotted drains shall be manufactured from helically corrugated steel pipe in accordance with AASHTO M 36M (M 36). At the end of the pipe there shall be two annular corrugations to permit the corrugated band to fully mesh with the pipe.

The grated assembly shall be made of structural steel in accordance with AASHTO M 183M (M 183), Grade 36. The assembly shall be suitably welded to the pipe and galvanized after assembly in accordance with AASHTO M 111. The grate shall be of the size and spacing shown on the plans and shall be welded on both sides to each bearing bar with a 5 mm (3/16 in.) fillet weld.

The size and thickness of the corrugated steel slotted drain pipe shall be as shown on the plans.

Slotted vane drain pipe shall be polyvinyl chloride in accordance with 907.23, and shall be of the diameter specified. The casting shall be in accordance with 910.05(b). The finish shall be standard black asphalt emulsion. Individual units shall have a minimum mass (weight) of 70 kg (155 lbs).

SECTION 909 – PAINT AND LIQUID EPOXY

909.01 General Requirements. All necessary facilities for inspection of materials and manufacture of paints, enamels, varnish, and ingredients shall be granted. Free access to all parts of the premises where any or all of these products are being prepared shall be allowed. Material Safety Data Sheets shall be provided.

10 Paint shall be furnished ready for use without modification and shall not settle, cake, curdle, liver, gel, or develop excessive change in viscosity between time of manufacture and time of use. It shall remain capable of being readily dispersed with a paddle, or other approved methods, to a consistency appropriate for the intended use. Paint may be sampled and tested at any time prior to use. If, for any reason, re-sampling and retesting following initial or prior approval is indicated, the latest test results shall prevail over all previous tests for material that has not been used. Previously approved paint which is later stored may be re-sampled and retested.

20 Paint shall be delivered in new containers of such strength, durability, design, fabrication, and material that the paint shall be suitably protected in transit and in storage against any change in characteristics which would cause rejection on the basis of laboratory or field evaluation. Each container shall bear a label which shows the name and address of the manufacturer, kind of paint, formula identification date of manufacture, and lot or batch number. The mass per volume (weight per gallon) kg/L (lb per gal.) of the paint shall be accurately determined at 25EC (77EF). The container shall be so filled that the net mass (weight) of the material in the container shall be the product of the mass per volume (weight per gallon) at 25EC (77EF) and the stated number of liters (gallons) in the container.

30 All labels shall be in accordance with the OSHA requirements for labeling of hazardous chemicals as described in the Hazardous Communications Standard.

909.02 For Metal. Paints for metal surfaces shall be in accordance with the requirements shown below.

(a) Zinc Primers.

40 **1. Two Component and Multi-Component Inorganic Zinc Silicate Primer.** These paints shall be of the self-cure type which, when mixed and applied in accordance with these specifications, shall cure without the use of a separate curing solution. The multi-component inorganic zinc silicate primers shall have a maximum of three components. The components of each type of paint shall be packaged in such proportions that when the full quantity of each component is mixed together, the specified mixed paint shall be yielded.

These paints shall be in accordance with the following requirements.

- a. Two component solvent based primer shall be in accordance with AASHTO M 300 Type I.
- b. Multi-component solvent based primer, with low volatile organic compounds for shop painting, shall be in accordance with AASHTO M 300 Type IA.
- c. Two component water based primer shall be in accordance with AASHTO M 300 Type II.

2. Single Package Inorganic Zinc Silicate Primer. The Inorganic Zinc Silicate Primer shall be a single package, self-curing type which, when stirred and applied in accordance with these specifications, cures without the use of a separate curing solution. It shall be in accordance with AASHTO M 300 Type III.

3. Organic Zinc Primer. Organic zinc primer shall be a self-curing type paint. It shall be in accordance with SSPC paint specification No. 20 type II with exceptions as follows:

Table I, total zinc dust, percent by mass (weight) of pigment requirement shall be a minimum of 87% metallic zinc. Table I, total zinc dust, percent by mass (weight) of total solids requirement shall be a minimum of 72% metallic zinc.

The organic zinc primer shall also be in accordance with the requirements as follows:

- a. The viscosity shall be 70 to 100 kreb units.
- b. The mass per volume (weight per gallon) shall be a minimum of 2.04 kg/L (17.0 lb/gal.).
- c. The dry time shall be a maximum of 1 h set-to-touch and 24 h dry hard when applied at 150 :m (6 mil) blade clearance to a tin coated steel panel at 25EC and 60% " 5% relative humidity.
- d. The infrared spectrum of the vehicle shall match the infrared spectrum of the vehicle of the sample submitted for formulation approval.
- e. The organic zinc primer shall not exceed 0.419 kg/L (3.50 lb/gal.) volatile organic compounds. The cured film shall not contain toxic heavy metals above the regulatory levels of 40 CFR 261.24.

- 90 f. The organic zinc primer shall be compatible with inorganic zinc and finish coat paints already on the bridge. The color shall be able to produce a distinct contrast with blast cleaned metal surface and the finish coat. The cured organic zinc film shall be compatible with a top coating of waterborne finish coat paint.

4. Approval of Formulation. The manufacturer shall obtain approval of the formulation prior to furnishing the primers. To obtain approval, the manufacturer shall submit to the Division of Materials and Tests the following:

- 100 a. A certified test report from an approved independent testing laboratory showing specific test results for all applicable quantitative requirements and resistance test requirements in these specifications. The report shall state the manufacturer's name, brand name of paint including formulation number, date of manufacture, number of the batch tested, beginning and ending dates of resistance tests, and, for the 2-component or multi-component paints, the exact mass (weight) ratio of each component used in the mixed paint tested.
- 110 b. A certification, in accordance with the applicable requirements of 916, indicating compliance with the requirements for the specific primer set out in these specifications.
- c. A current material safety data sheet shall be submitted with the initial formulation approval package.

5. Reapproval of Formulation. Reapproval will be required:

- a. every five years;
- 120 b. each time there is a change in formulation or the manufacturing process;
- c. if three consecutive years elapse without furnishing material;
- d. it may be required when test of material furnished indicate non-conformance with any of the specified requirements.

130 **(b) Epoxy Intermediate Paint.** Epoxy intermediate paint shall be a two component coating consisting of an epoxy resin and a curing agent, together with prime and filler pigments, colorants, gellant, leveling agents and solvents. When mixed, this coating shall be suitable for application over inorganic and organic zinc primers and shall be compatible with a polyurethane finish coat. The color of this coating shall contrast significantly from the other coatings within the coating system.

The mixed paint shall be in accordance with the requirements as follows:

	Volatile organic compounds, ASTM D 3960, Max.	336 g/L
	Volume solids, ASTM D 2697, Min.....	60%
140	Set-to-touch, ASTM D 1640, 175 µm wet film, 25 " 1EC, Max.....	4 h
	Potlife, 25 " 1EC, Min.	6 h
	Mass (weight)/volume variance from the initially approved batch, ASTM D 1475, 25EC, Max.....	0.060 kg/L
	Total solids variance from the initially approved batch, ASTM D 2369, Max.....	3.0%

The infrared spectra of each component and of the mixed coating shall essentially match the spectrums of the initially approved batch.

- 150 **(c) Polyurethane Finish Coat.** Polyurethane finish coat shall be a two component polyester or acrylic aliphatic polyurethane suitable for use as a finish coat over epoxy intermediate paint.

The mixed paint shall be in accordance with the requirements as follows:

	Volatile organic compounds, ASTM D 3960, Max.	336 g/L
	Volume solids, ASTM D 2697, Min.....	60%
	Set-to-touch, ASTM D 1640, 127 µm wet film, 25 " 1EC, 50 " 10% relative humidity, Min.....	30 min
160	Total Solids ASTM D 2369, Min.....	70%
	Specular gloss, 60E, ASTM D 523, Min.	75
	Viscosity, ASTM D 562, Kreb Units, Max.	100
	Contrast ratio, ASTM 2805, 127 µm wet film thickness dried 24 h @ 25 " 2EC on Leneta Form 2A or 2C, Min.	0.95
	Dry hard, ASTM D 1640, 127 µm wet film, 25 " 1EC, 50 " 10% relative humidity, Max.	24 h

The infrared spectra of each component and of the mixed coating shall essentially match the spectrums of the initially approved batch.

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The color of the dried paint film shall match the color number of Federal Standard 595a as follows:

Color No.	Color
14260	Green
15450	Light Blue
17886	White
13538	Yellow
13711	Buff
17038	Black

(d) Waterborne Finish Paint. The waterborne finish coating shall be a single package, high build acrylic emulsion for use as a finish coat over inorganic and organic zinc primers. It shall be compatible with and adhere to the cured zinc primers.

180 **1. Vehicle Component.** The vehicle shall consist of an acrylic emulsion together with the necessary antifoamers, cosolvents, coalescing agent, preservatives, and antifreeze in order to produce a coating in accordance with this specification.

2. Pigment Component. The active pigment shall consist of titanium dioxide in accordance with ASTM D 476, type IV, and non-reactive color retentive tinting pigments. The pigment shall contain extenders and additives as required for proper application.

190 **3. Mixed Paint Properties.** The mixed paint shall be in accordance with the requirements as follows:

200 Viscosity, ASTM D 562, Kneb Units..... 80 - 100
Mass (weight)/volume, ASTM D 1475, deviation from
approval formulation, Max.0.024 kg/L (0.2 lb/gal.)
Pigment grind, ASTM D 1210, Hegman, Min. 5
Total solids, % by mass (weight), ASTM D 2369, Min.50
Vehicle solids, % of vehicle by mass (weight), Min.....40
Dry time, ASTM D 1640, 75 µm (3 mils) wet film on a tin
coated steel panel @ 25 " 1EC and 50 " 5% relative humidity, Max:
Set-to-touch, h 1
Dry hard, h.....24
Hiding power, 150 µm 6 (mils) wet film on most
black and white chart paper, dry film hiding.....Complete
Specular gloss, 60E, 250 µm (10 mils) wet film on a tin
coated panel, dried 48 h @ 25EC and 50 " 5% relative
humidity, ASTM D 523.....15 - 25
pH, ASTM E 707.0 - 9.0
Volatile organic compounds, ASTM D 3960
Max. 0.180 kg/L (1.50 lb/gal.)

210 The infrared spectrum of the vehicle when extracted from the mixed paint in accordance with ASTM D 3168 shall match the infrared spectrum of the sample submitted for formulation approval.

The mixed paint shall be in accordance with the requirements of Sections 5.4 through 5.17 of SSPC paint specification No. 24.

The cured waterborne finish paint shall not contain toxic heavy metals above the regulatory levels of 40 CFR 261.24.

220 **4. Color.** The color of the dried paint film shall match the color number of Federal Standard 595a as follows:

Color No.	Color
24227	Green
24466	Light Green
25526	Light Blue
27780	White
23538	Yellow
23717	Buff
27038	Black

5. Approval of Formulation. The manufacturer shall obtain approval of the formulation prior to furnishing the waterborne finish paint. The formulation approval shall be in accordance with 909.02(a)4 and 909.02(a) 5.

230 **(e) Finish Coat for Weathering Steel.** The finish coat shall be an aliphatic polyurethane or a waterborne acrylic paint. It shall be suitable for use as a finish coat over epoxy intermediate paint. The mixed paint shall be in accordance with the requirements as follows:

Specular gloss, 60E, ASTM D 523, Max.....6.0
Viscosity, ASTM D 562, Kneb Units, Max. 100
Mass (weight)/volume variance from the initially approved
batch, ASTM D 1475, 25EC, Max..... 0.048 kg/L
Total solids variance from the initially approved
batch, ASTM D 2369, Max..... 2.0%
Volatile Organic Compounds, ASTM D 3690, Max.....336 g/L

240 The dried paint film shall match color number 30045 of Federal Standard 595a.

909.03 Structural Steel Coating System. This coating system shall consist of an inorganic zinc primer, an epoxy intermediate paint, and a polyurethane finish coat for the painting of steel bridges and other structural steel. All of the coatings within any coating system shall be manufactured by the same manufacturer and shall be compatible with one another. All coatings shall be in accordance with 909.02.

250 **(a) Toxicity.** The cured film of each coating within the structural steel coating system shall not contain any toxic heavy metals above the limits of the regulatory levels of 40 CFR 261.24, table 1, when tested in accordance with EPA TCLP, or contain any other material which will require characterization as a hazardous waste for the disposal of the dried film.

260 **(b) Resistance.** The coating system shall be tested in accordance with the requirements of NEPCOAT, Specification Criteria For Protective Coatings, dated June 6, 1996. The coating system shall be in accordance with all of the acceptance criteria and shall maintain a specular gloss retention of 60% relative of the initial gloss and a maximum color change of 15 ΔE for Test No. 3, Weathering Resistance.

260 **(c) Approval of Structural Steel Coating System.** The manufacturer shall obtain approval of each structural steel coating system prior to furnishing any of these coatings. An approved list of Structural Steel Coating Systems will be maintained by the Department. The list will specify the manufacturer's designation of each coating of structural steel coating system. Manufacturers who desire to have products added to the list of Structural Steel Coating Systems shall submit the following documentation to the Materials and Tests Division.

- 270 1. A certified test report from an independent testing laboratory which provides test results for all quantitative requirements and resistance test requirement for each coating and for the coating system in these specifications. The test report shall include the manufacturer's name, brand name of each coating, formulation identification of each coating, batch numbers, beginning and ending dates of each test, date of manufacture for each coating, and the exact mass (weight) and volume ratio of each component used for mixing multiple component coatings.
- 280 2. Material safety data sheet for each coating.
3. Product data sheet for each coating. The product data sheets shall be in accordance with NEPCOAT Specification Criteria For Protective Coatings, dated June 6, 1996.
4. A QCP which includes all aspects of the production process for each coating, starting with raw materials and concluding with the shipment of the finished products. The QCP shall include sampling and testing frequency and specific test used for the quality control of each product.
- 290 5. Documentation of quality assurance within the manufacturer's laboratory.

6. Performance history indicating that the specific coating system has performed successfully for a minimum of three years. The performance history shall include the name, address and telephone number of the structure owner including the name of a responsible contact person, location of the structure and dates of coating application and inspection.

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(d) Structural Steel Coating System Re-approval. Re-approval will be required as follows:

1. each time there was a change in the formulation or the manufacturing process of each coating;
2. if three consecutive years elapse without furnishing any of the approved coatings;
3. when testing of the coating furnished indicates continual non-compliance with the specifications; and
4. when field evaluations indicate that the coating system does not provide the required protection to the structural steel.

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909.04 Field Paint for Wood or Metal. The primers for field paint shall be formulated for minimal surface preparation, provide adhesion to the substrate and be compatible with the finish coat. The primers shall not contain lead, chromium or other heavy metals which would require classification as a hazardous waste upon removal. The primers shall comply with the current IDEM VOC regulations and shall be used as follows:

- a. For unpainted galvanized steel and other ferrous metals, use one coat of a zinc dust-zinc oxide pigmented primer.
- b. For non-ferrous metals, use one coat of primer formulated for use on non-ferrous metals.

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The field paint finish coat shall be an exterior type coating. It shall be chalk resistant, gloss retentive and suitable for application by brush, roller or spray. This coating shall comply with the current IDEM VOC regulations and shall not contain lead, chromium or other heavy metals which would require classification as a hazardous waste upon removal. The color of this coating shall be as specified.

909.05 White and Yellow Traffic Paint.

(a) Standard Traffic Paint.

340 **1. General Requirements.** White and yellow traffic paint shall be used on pavements for centerlines, lane lines, or as otherwise specified. In addition to its other requirements, when glass beads are applied, it shall be such that it shows capillary action in the interstices and voids existing between the beads sufficient to cause the level of the paint to be raised approximately 2/3 the diameter of the beads to provide anchorage and refraction. The capillary action shall be such that it does not cause complete envelopment. The paint, as furnished, shall contain no glass beads.

350 The paint shall be ground to a uniform consistency and shall permit satisfactory application by the pressure spray type of painting machine currently in use by the Department. This painting equipment is designed to apply reflectorized lines, using the drop-on bead method, 100 mm (4 in.) to 150 mm (6 in.) wide, at a wet film thickness of 0.381 mm (0.015 in.) on clean, dry pavements at ambient temperatures of 4EC (40EF) or higher at speeds of 16.09 to 24.14 km/h (10 to 15 mph). The material shall have physical characteristics which permit it to be pumped through gear type pumps from the shipping container into the paint tanks, and by compressed air from the paint tanks through the paint machine plumbing system at a minimum ambient temperatures of 4EC (40EF).

360 The paint shall be furnished ready for use without thinning or other modification and shall not settle, cake, curdle, liver, gel, or show excessive change in viscosity in the container during a period of one year after manufacture and shall be capable of being broken up with a paddle to a smooth consistency. The manufacturer shall furnish any necessary information as to special storage requirements. The paint may be rejected if it contains skins, thickened or jelly-like layers or lumps, coarse particles, dirt, or other foreign material. The composition of the pigments and vehicles of the paints are at the option of the manufacturer, provided the paints conform with the requirements specified herein.

370 The paint shall be supplied in new removable head 210 L (55 gal.) drums which conform to DOT Specification 17-H, or in new 19 L (5 gal.) removable lid buckets conforming to the appropriate DOT Specifications. The drums shall be filled with 190 L (50 gal.) of paint. Volume measurements shall be based on a liquid temperature of 25EC (77EF). Drums shall be provided with reusable multiseal sponge gaskets, of a type which prevents the paint from skinning during storage, and shall be equipped with outside locking rings or clamps. Each drum shall show true mass (weight), gross mass (weight), net mass (weight), equivalent net volume (gal.), name and address of manufacturer, batch number, kind of paint, color, and date of manufacture.

2. Specific Requirements.

380		Min.	Max.
	Pigment, Federal Standard 141A, Method 4022,		
	percent by mass (weight).....	54	60
	Titanium Dioxide, ASTM D 476, Types II, III, or IV,		
	white only, g/L (lb/gal.) of paint.....	96 (0.8)	---

	Medium Chrome Yellow, ASTM D 211, Type III,	
	yellow only, g/L (lb/gal.) of paint,.....	144 (1.2) ---
	Other pigments may be used provided the amount of pigment is such that there will be a minimum of 0.125 kg of pure lead chromate per liter (1.04 lb/gal.) of paint.	
390	Vehicle Solids, percent of vehicle by mass (weight), Federal Standard 141A, Method 4053	40 ---
	Total Non-Volatiles, Federal Standard 141A, Method 4042, percent by mass (weight)	74 ---
	Viscosity @ 25EC (77EF), ASTM D 562, Krebs Units	70 80
	Luminous Directional Reflectivity, ASTM E 308 or E 97, percent	
	White.....	84 ---
	Yellow.....	50 ---
400	Color, yellow only, x-y C.I.E. coordinates for green limit, FHWA color chart of June 1965.....	Match the green limit " 8%
	Dry time to no pick-up ASTM D 711, wet film 380 " 25:m (15 mils " 1 mil), with bead cover approx. 719 g/L (6 lb/gal.), minutes.....	10 30
	Contrast ratio, ASTM D 2805, wet film 380 " 25:m (15 " 1 mil), black - white chart paper, air dried at least 16 h.....	0.96 ---
410	Flexibility, Federal Specifications TT-P-85D.....	No breaking or cracking
	Uncombined (free) water, percent, Federal Standard 141 A, Method 4081.....	--- 1.0

(b) Fast Dry Traffic Paint.

1. General Requirements. The general requirements specified for standard traffic paint in 909.05(a)1 shall apply except as modified herein.

420 The paint shall be ground to a uniform consistency, and it shall permit satisfactory application by the pressure spray type of painting machine currently in use by the Department. This painting equipment is designed to apply reflectorized lines, using a pressurized bead application method, 100 mm to 150 mm (4 to 6 in.) wide, at a wet film thickness of 380 :m (0.015 in.) on clean dry pavement, with the material being heated at a maintained temperature from ambient air temperature to a maximum of 82EC (180EF), at the atomized spray gun, at a minimum ambient temperature of 4EC (40EF). The material shall be capable of being applied under these conditions at speeds of 16 to 24 km/h (10 to 15 mph). The material shall have physical characteristics which permit it to be pumped at a minimum temperature of 4EC (40EF) through pumps from the shipping container into the paint tank on the paint machine, and then by pumps
430 through the paint machine plumbing system to and through the heat exchanger and to the spray gun at the proper pressure and temperature.

2. Specific Requirements. The paint shall dry to a no tracking condition in no more than 60 s. The no tracking condition shall be determined by actual application on the pavement at a wet film thickness of 380 :m (15 mils) with white or yellow paint covered with glass beads at a rate of 0.7 kg/L (6 lb/gal.). The paint lines for this test shall be applied with the specialized striping equipment operated so as to have the paint at temperatures up to 82EC (180EF) at the spray orifice. This maximum no tracking time shall not be exceeded when the pavement temperature varies from 2EC (35EF) to 49EC (120EF), and under all humidity conditions providing that the pavement is dry. The no tracking time shall be determined by passing over the paint line 60 s after paint application, in a simulated passing maneuver at a constant speed of 48 to 64 km/h (30 to 40 mph) with a passenger car. A line showing no visual deposition of the paint to the pavement surface when viewed from a distance of approximately 15 m (50 ft) from the point where the test vehicle has crossed the line shall be considered as showing no tracking and conforming to the requirement for field drying conditions. This field dry time test shall be used for production samples only.

In addition to the above, the paint shall meet the following requirements:

	Min.	Max.
Pigment, Federal Standard 141A, Method 4022, percent by mass (weight).....	54	60
Titanium Dioxide, ASTM D 476, Types II, III, or IV, white only, g/L (lb/gal.) of paint.....	96 (0.8)	---
Medium Chrome Yellow, ASTM D 211, Type III, yellow only, g/L (lb/gal.) of paint	144 (1.2)	---
Other Pigments may be used, provided the amount of pigment is such that there will be a minimum of 0.125 kg/L (1.04 lbs/gal.) of pure lead chromate per gallon of paint.		
Vehicle Solids, percent of vehicle by mass (weight), Federal Standard 141A, Method 4053	35	---
Total Non-Volatiles, Federal Standard 141A, Method 4042, percent by mass (weight)	72	---
Viscosity @ 25EC (77EF), ASTM D 562, Krebs Units	80	100
Luminous Directional Reflectivity, ASTM E 308 or E 97, percent		
White.....	84	---
Yellow.....	50	---
Color, yellow only, x-y C.I.E. coordinates for green limit, FHWA color chart of June 1965.....	Match the green limit " 8%	
Contrast ratio, ASTM D 2805, wet film 380 " 25 :m (15 " 1 mil) black - white chart paper, air dried at least 16 h	0.96	---
Uncombined (free) Water, Federal Standard 141A, Method 4081, percent.....	---	1.0

(c) White and Yellow Waterborne Traffic Paint. White and yellow waterborne traffic paints shall consist of an emulsion of pigmented binder.

When glass beads are induced into the paint lines, the paint shall provide capillary action in the interstices and voids between the glass beads sufficient to cause the level of paint to raise approximately two thirds the diameter of the glass beads. This capillary action shall not cause complete envelopment of the glass beads. The paint as furnished shall not contain glass beads. The paint shall be ground to a uniform consistency, and it shall permit satisfactory application by the pressure-spray type of painting equipment. The painting equipment shall use a pressurized bead application method that is designed to apply 100 to 150 mm (4 to 6 in.) reflectorized paint lines at paint temperature up to 65EC (150EF). The paint shall be capable of being applied at speeds of 15 to 25 km/h (10 to 15 mph).

The paint shall not darken under the heating conditions of application, or show appreciable discoloration due to sunlight exposure and aging of the paint lines. The paint shall be furnished ready for use without thinning, screening, or other modifications and shall not settle, cake, curdle, liver, gel, or have an excessive change in viscosity in the container during a period of one year after manufacture. The paint shall be capable of being stirred to a uniform consistency. The paint shall be able to withstand variations of temperatures when stored outside in the containers as delivered, and in an environment above 5EC (40EF). All paint furnished under these specifications will be rejected if it contains skins, thickened or jelly-like layers, lumps, coarse particles, dirt, or other foreign materials which prevent the proper application of the paint, or produces a non-uniform paint line. All paint which cannot be transferred by pumps on the paint equipment from the shipping containers and through the paint equipment due to excessive clogging of screens, filters, or paint guns will be rejected.

The paint shall dry to a no-tracking condition in less than 60 s. The no-tracking condition shall be determined by actual application of the paint on the pavement at a wet film thickness of 380 Fm (15 mils) with glass beads applied at a rate of 0.7 kg/L (6 lb/gal.). The paint lines for the determination of no-tracking condition shall be applied with the specialized painting equipment operated so as to have the paint at application temperatures up to 60EC (140EF) at the spray guns. The maximum no-tracking time shall not be exceeded when the pavement temperature varies from 10EC to 50EC (50EF to 120EF), and with all relative humidity conditions providing that the pavement is dry. The no-tracking time shall be determined by passing over the paint line 60 s after the paint application, in a simulated passing maneuver at a constant speed of 50 to 65 km/h (30 to 40 mph) with a passenger car. A paint line with no visual deposition of the paint to the pavement surface when viewed from a distance of approximately 15 m (50 ft) from the point where the vehicle crossed the paint line shall be considered as showing a condition of no-tracking and being in accordance with the requirement.

1. Composition Requirements. The exact composition of the waterborne traffic paint shall be left to the discretion of the manufacturer, provided that the finished product is in accordance with all of the specification requirements.

530 The pigment portion of these paints shall be a combination of prime and extender pigments as required to produce either white or yellow waterborne traffic paint in accordance with the color and other requirements of the finished product. The yellow waterborne traffic paint pigment shall contain pigment yellow Colour Index Number 65 and/or 74 and/or 75. The white waterborne traffic paint pigment shall contain titanium dioxide in accordance with ASTM D 476. The non-volatile portion of the vehicle shall be composed of a 100% acrylic polymer.

540 The cured film of waterborne traffic paint shall not contain toxic heavy metals above the limits of the regulatory levels of 40 CFR 261.24 Table 1 when tested in accordance with EPA Toxicity Characteristics Leaching Procedure Test Method 1311 in Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods, EPA publication SW-846. It shall not contain other hazardous materials which would require characterization as a hazardous waste for the disposal of the dried film.

2. Specific Requirements.

		Minimum	Maximum
	Volume solids, ASTM D 2697, %	58.0	--
	Total solids by mass, ASTM D 3723, %	73.0	--
550	Pigment by mass, ASTM D 3723, %	45.0	57.0
	Vehicle solids by mass of the vehicle, %	44.0	--
	Viscosity, ASTM D 562, Kneb Units	75	95
	Unit mass @ 25EC (77EF) ASTM D 1475, kg/L (lb/gal.)	1.498 (12.50)	--
560	Unit mass @ 25EC (77EF), variation between manufacturer's production batches, ASTM D 1475, g/L (lb/gal.)	--	24 (0.20)
	Dry time, ASTM D 711, 380 Fm (15 mils) wet film thickness, at 25EC (77EF), 50% " 5% relative humidity, airflow of less than 1.4 m ³ /min (50 ft ³ /min), without glass beads,	--	10 min

570	Luminous directional reflectivity ASTM E 97, ASTM E 308, 380 Fm (15 mils) wet film thickness, air dried a minimum of 16 h, %		
	White	84	--
	Yellow	50	57
580	Color, yellow only, x & y C.I.E. Coordinates for the strong limits of FHWA color chart PR1, 380 Fm (15 mils) wet film thickness, air dried a minimum of 16 h, measured on white background, % deviation	Match the strong limits	" 6.00
	Coarse material retained on a 600 Fm (No. 30) sieve, ASTM D 185, %	--	0.05
590	Bleeding ratio, Federal Specifications TT-P-1952B, except asphalt saturated felt paper shall be in accordance with ASTM D 226 Type I	0.97	--
	Contrast ratio, ASTM D 2805, 254 Fm (10 mils) wet film thickness on Leneta Form 2A or 2C, air dried a minimum of 16 h	0.96	--
	Volatile organic compounds, ASTM D 3960, g/L (lb/gal.)	--	150 (1.25)
600	Abrasion resistance, Federal Specifica- tions TT-P 1952B, L	190	--
	Freeze-thaw stability, Federal Speci- fication TT-P 1952B, change in consis- tency, Kreb Units	--	10
	Heat stability, Federal Specifications TT-P 1952B, change in consistency, Kreb Units	--	10
610	Scrub resistance, ASTM D 2486, with abrasive medium and shims, cycles	300	--

Water resistance, Federal Specification
TT-P 1952B

Film shall not
soften, blister,
wrinkle, or lose
adhesion.

620

Flexibility, Federal Specifications
TT-P-1952 B

No cracking or
flaking of film.

Infrared spectrum of the vehicle,
ASTM D 3168

Shall match spectrum
of manufacturer's
previously submitted
samples.

Dilution test shall be capable of dilution with water at all levels without curdling or precipitation such that wet paint can be cleaned up with water only.

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3. Formulation Approval. The manufacturer shall obtain approval of the waterborne traffic paint formulations prior to furnishing the paints. To obtain approval, the manufacturer shall submit the following to the Materials and Tests Division:

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a. A certified test report from an independent testing laboratory showing specific test results for all quantitative requirements and resistance test requirements in these specifications. The report shall state the manufacturer's name, brand name of paint, formulation identification, day, month and year of manufacture, number of batch tested, and the beginning and ending dates of each test.

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b. A type A certification in accordance with 916 from the paint manufacturer's laboratory.

c. A quality control plan which encompasses all aspects of the production process starting with the raw materials and concluding with the shipment of the finished product. The quality control plan shall provide for a 95% or greater statistical assurance that the paint will be in accordance with the specifications, and include specific type and frequency of sampling and testing.

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d. Documentation indicating that the manufacturer's quality control laboratory is in accordance with AASHTO R 18.

e. Documented information detailing the past history and experience with the specific formulation in terms of service life and the specific conditions of use. The documented information shall include specific details about durability and reflectivity of the paint.

- f. The specific paint formulation by mass and volume of each of the raw materials contained in the finished paint.
- g. Material safety data sheets for the finished paint and for each raw material contained in the finished paint.
- h. An infrared spectrum of the paint's vehicle extracted from the finished paint in accordance with ASTM D 3168.

670 **4. Formulation Reapproval.** The waterborne paint formulation reapproval will be required as follows:

- a. Each time there is a change in the formulation or manufacturing process.
- b. When testing of the waterborne paint indicates continual non-compliance with these specifications.
- c. When field evaluations indicate that the paint does not provide the required performance.

680 **909.06 Blank.**

909.07 Blank.

909.08 Blank.

909.09 Epoxy Penetrating Sealers.

690 **(a) Polysulfide Type.** The material shall be a system composed of a mixture of equal parts by volume of components A and B. Component A shall be a solution of totally reactive epoxy resin, which may be cut back with a reactive diluent, such as cresyl glycidyl ether. Component B shall be a solution of the specified liquid polysulfide polymer and an amine curing agent compatible with the epoxy resin. The use of butyl glycidyl ether in either component shall be prohibited.

 Neither component shall contain a residual constituent which is unreactive with the epoxy resin. An amount of liquid polysulfide polymer sufficient to comply with the mercaptan content, total sulfur, and total sulfur/mercaptan ratio requirements given below shall be contained within the component B.

700 Mineral fillers, non-volatile, or non-reactive extenders shall not be permitted in either component. Each component shall have a usable shelf life of at least six months from the date of delivery.

The epoxy resin shall be manufactured from epichlorohydrin and bisphenol A, shall contain no more than trace amounts of hydrolyzable chlorine, and may contain sufficient reactive diluent, such as cresyl glycidyl ether, to conform to the specific requirements of 909.09(c).

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(b) Unmodified Type. The material shall be a system composed of a mixture of equal parts by volume of components A and B. Component A shall be a solution of a totally reactive epoxy resin, and component B shall be a solution of an amine curing agent compatible with the epoxy resin. The use of butyl glydicyl ether in either component shall be prohibited.

Neither component shall contain a residual constituent which is unreactive with the epoxy resin. Mineral fillers or non-volatile extenders shall not be permitted in either component. Each component shall have a usable shelf life of at least six months from the date of delivery.

720

The epoxy resin shall be manufactured from epichlorohydrin and bisphenol A, shall contain no more than trace amounts of hydrolyzable chlorine, shall contain no reactive diluents, and shall be in accordance with 909.09(c).

(c) Specific Requirements. Specific requirements for each type of sealer shall be as shown in the table.

Property	Polysulfide Type	Unmodified Type	Test Method
RESIN			
Epoxide Equivalent	180-195	180-195	ASTM D 1652
Viscosity @ 25EC, (77EF) Poises	5-7	100-180	ASTM D 2393
Color (Gardner) Max.	5	5	ASTM D 1544
COMPONENT A			
Viscosity @ 25EC, (77EF) cps, Max.	40	40	ASTM D 2393
Mass (Weight) per Epoxy Equivalent	180-195	180-195	ASTM D 1652 Corrected to 100% Solids Basis
Color	Clear Amber	Clear Amber	Visual
Infra Red Spectrum	Shall Essentially Match Std. Spectrum	Shall Essentially Match Std. Spectrum	AASHTO T 237
COMPONENT B			
Viscosity @ 25EC, (77EF) cps, Max.	40	40	ASTM D 2393
Color	Clear Amber	Clear Amber	Visual
Infra Red Spectrum	Shall Essentially Match Std. Spectrum	Shall Essentially Match Std. Spectrum	AASHTO T 237
Total Sulfur, % Min. Corrected to 100% Solid Basis	11.0		ASTM E 443, or other Approved Method
Mercaptan, % Min.	1.8		ITM 602
Ratio of Total Sulfur % to Mercaptan %	6.2-8.0		

1/1 VOLUME MIXTURE OF A AND B			
Viscosity @ 25EC, (77EF) cps, Max.	40	40	ASTM D 2393
Total Solid, %, Min.	50	50	ASTM D 1644 (Note 1)
Ash %, Max.	0.5	0.5	ASTM D 482
Flexibility	No Breaking or Cracking of film	No Breaking or Cracking of Film	ITM 604
Moisture Perme- ability, %, Max.	0.8	0.8	ITM 605
Color	Clear Amber	Clear Amber	Visual (Note 2)
Set to Touch, Hrs. Max.	4 (Note 3)	4 (Note 3)	FED. Test Method Std. 141 (Note 4)

(Note 1) Method A, except sample size shall be 3.0 grams " 0.1 gram.

(Note 2) Poured on glass plate, and cured 48 h @ 21EC to 27EC (70EF to 80EF).

(Note 3) Applied to tin-coated steel panel, approximately 20 ga., previously warmed to 32EC " 1EC (90EF " 2EF).

(Note 4) Method 4061.1, applied at mixture temperature of 32EC " 1EC (90EF " 2EF).

The polysulfide polymer used in formulation of polysulfide sealer shall be a difunctional mercaptan made from 98 mole percent of bis, 2-chlorethyl, formal and 2 mole percent of trichloropropane, and shall be in accordance with the following requirements:

Property	Requirements	Test Method
Specific Gravity @ 20/20EC	1.24-1.30	ASTM D 1963
Viscosity at 25EC, Poises	7-12	ASTM D 2393
PH, Water Extract	6.0-8.0	AASHTO T 200
Moisture Content, %	0.1 Max.	Fed Test Method Std. 141A Method 4082
Pour Point CE	-26.8 Max.	ASTM D 97
Molecular Mass Av.	1000 Max.	Empirical Formula
Flash Point, (Cleveland) CE	200 Min.	AASHTO T 48
Sulfur, %	36-40	ASTM D 1552
Color, Hellige	9-12	Fed Test Method Std. 141A Method 4242

(d) Low Temperature Epoxy Penetrating Sealer. A low temperature epoxy penetrating sealer shall consist of a system composed of a mixture of equal parts by volume of a totally reactive epoxy resin solution, and a solution of an amine curing agent. The epoxy materials shall be in accordance with 909.09(a) or 909.09(b). The material, when mixed in accordance with the manufacturer's recommendations, shall be capable of complete curing when applied to a concrete surface at a temperature of 2EC (35EF) or above, and with an ambient air temperature of 2EC (35EF) or above. The material shall be in accordance with 909.09(c), except the set-to-touch shall be determined at -7E " 1EC (20E " 2EF) when applied to a tin coated steel panel at a mixture temperature of 25E " 1EC (77E " 2EF).

(e) Packaging and Marking. Each component shall be packaged in clean, steel containers. Containers for component B shall be lined with a material inert to chemical reaction with the contents.

Each container shall be clearly marked with the product's identification, component designation (A or B), manufacturer's name, date of manufacture, formulation number, batch number, mixing directions, and such warning information as may be appropriate or required by law. A batch shall consist of a single charge of all ingredients in a mixing vessel and is not to be confused with the formulation number.

(f) Approval of Formulation. Prior to furnishing any material, the manufacturer shall submit the following to the Division of Materials and Tests:

1. A 2.0 L (1/2 gal.) sample of each separate component shall be submitted. Each sample container shall be marked with component designation, A or B, manufacturer, and manufacturer's formulation number.
2. A type A certification in accordance with 916 shall be submitted to cover the epoxy resin, the polysulfide polymer, component A, component B and the mixture of the two components. The certification shall contain the same identifying information as set out above for each container.
3. For an initial formulation submission, the manufacturer shall furnish an infra-red curve for each separate component. Each infra-red curve shall have the same identifying information as set out above for each container.
4. A current Materials Safety Data Sheet for each component and for the mixture shall be provided with the initial formulation submitted.

Formulation approval shall remain valid for five years from date of such approval unless Department testing of a production batch indicates a failure, or if no material has been received from the approved manufacturer for three consecutive years within the five year interval. Approval of the formulation in accordance with requirements 1 and 2 of 909.09(e) shall again be required for either situation. Changed or revised formulations shall be subjected to all of the approval requirements set out above. Submission for formulation approval shall be limited to three attempts at least 90 days apart.

909.10 Proprietary Portland Cement Concrete Sealers. An approved List of Proprietary Portland Cement Concrete Sealers will be maintained by the Department. The list will specify the manufacturer, sealer designation, concrete curing prior to sealer application, sealer application rate, method of sealer application, and any additional requirements for specific sealers. The proprietary portland cement concrete sealers shall be delivered to the jobsite in unopened containers with the manufacturer's numbered seal intact.

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Sealer manufacturers wishing to have a sealer added to the Approved List of Proprietary Portland Cement Concrete Sealers shall submit to the Division of Materials and Tests a certification of compliance of their product with the requirements of NCHRP 244, Series IV, Southern climate weathering test. The certification shall be in accordance with the applicable requirements of 916, indicate the generic type of sealer, state the minimum amount of active ingredients, and include a dated report with results for the referenced tests conducted by a recognized laboratory. A recognized laboratory is a state highway agency testing laboratory, or any testing laboratory regularly inspected by the Cement and Concrete Reference Laboratory of the National Institute of Standards and Technology. Proof of such inspection shall be furnished with the test report.

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The minimum acceptable amount of active ingredients shall be 20% for silane based sealers and 15% for all other types, such as siloxane based, etc.

A current Material Safety Data Sheet shall be submitted with the certification.

Upon acceptance, the sealer will be added to the List of Approved Proprietary Portland Cement Concrete Sealers.

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A sealer which does not perform well in the field or does not comply as expected with field testing will be removed from the Approved List.

909.11 Epoxy-Resin-Base System for Bonding Plastic Concrete to Hardened Concrete. Two-component, epoxy-resin bonding systems for use in bonding freshly mixed concrete to hardened concrete shall be in accordance with ASTM C 881 for type II, grade 2, and the class consistent with the ambient temperature as follows: class A for use below 4EC (40EF); class B for use between 4EC (40EF) and 16EC (60EF); and class C for use above 15.5EC (60EF). Material furnished under this specification shall be covered by a type C certification in accordance with 916.

830

SECTION 910 – METAL MATERIALS

910.01 Reinforcing Bars and Dowel Bars.

10 **(a) General.** Unless otherwise specified, bars for concrete reinforcement shall be deformed billet steel, grade 420 (60). The bars for cement concrete pavement shall be deformed billet steel, except tie bars that shall be bent and subsequently straightened during construction shall be deformed bars in accordance with ASTM A615/A615M, grade 300 (40). Tie bar assemblies used in lieu of bent tie bars shall be in accordance with the minimum total ultimate strength and minimum total yield strength requirements specified for bent tie bars; bend test and elongation will not be required.

Reinforcing steel used in precast or precast prestressed concrete structural members, including deck panels, shall be in accordance with ASTM A615/A615M, grade 420 (60).

20 Reinforcing bars will be jobsite sampled in accordance with the Frequency Manual and, when shipped to the project site, the bars shall be accompanied by the types of certifications specified in the Frequency Manual and in accordance with 916. As an alternate procedure, the reinforcing bars may be furnished by selecting bars made by a manufacturer on the list of Certified Uncoated Reinforcing Bar Manufacturers and in accordance with ITM 301. When shipped to the project site, the reinforcing bars shall be accompanied by the types of certifications specified in ITM 301 and in accordance with 916.

(b) Specific Requirements.

30 **1. Billet Steel Bars.** Billet steel bars shall be in accordance with ASTM A615/A615M.

2. Threaded Tie Bar Assembly. The threaded tie bar assembly shall be deformed billet steel, grade 420 (60), in accordance with 910.01(b)1 and a coupling device. The tie assembly shall achieve a minimum load of 525 MPa (76.144 kip/in²). An epoxy coating with a minimum film thickness of 150 Fm (6 mils) shall be applied to the coupling device.

40 **3. Splicing Systems.** Reinforcing steel splicing systems shall be selected from the list of approved Reinforcing Steel Splicing Systems. A manufacturer may request to have a splicing system added to the list by submitting three randomly selected epoxy coated bars of each bar designation to be included as an approved splicing system on the list. The samples furnished shall be assembled. The splicing system will be tested for tensile strength in accordance with ASTM A 370 and shall reach 150% of the specified yield on all three samples for each bar size submitted. Splicing systems demonstrating consistent, repeatable, and passing test results will be added to the list. Approved bar designations will be noted on the list.

4. Blank.

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5. Welded Steel Wire Fabric for Concrete Reinforcement. Welded smooth steel wire fabric for concrete reinforcement shall be in accordance with ASTM A 185, except as follows:

- a. The wire used in manufacturing the fabric shall be as drawn, not galvanized, unless otherwise specified.
- b. The fabric shall be furnished in flat sheets unless otherwise permitted or specified.
- c. Weld shear tests of fabric will be performed on the test specimens obtained for testing tensile properties in accordance with the Frequency Manual. If there is weld shear failure, additional test specimens shall be obtained in accordance with ASTM A 185.

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6. Welded Deformed Steel Wire Fabric for Concrete Reinforcement.

Welded deformed steel wire fabric for concrete reinforcement shall be in accordance with ASTM A 497, except as follows:

- a. The wire used in manufacturing the fabric shall be in accordance with ASTM A 496.
- b. The fabric shall be furnished in flat sheets unless otherwise specified or permitted.
- c. Weld shear tests of fabric will be performed on the test specimens obtained for testing tensile properties in accordance with the Frequency Manual. If there is shear failure, additional test specimens shall be obtained in accordance with ASTM A 497.

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7. Uncoated 7 Wire Strand for Prestressed Concrete. Uncoated 7 wire strand for prestressed concrete shall be in accordance with ASTM A 416. The strand shall have the minimum tensile strength of and initial tension shown on the plans.

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Low relaxation strand with a nominal diameter of 12.70 mm (1/2 in.) and a cross sectional area of 108 mm² (0.167 in²) shall have a breaking strength of 20 400 kg (45,000 lb).

Uncoated 7 wire strand shall be covered by the type of certification specified in the Frequency Manual and in accordance with 916.

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8. Steel Spiral Reinforcement. Steel spiral reinforcement shall be either:

- a. deformed billet steel, ASTM A 615/A 615M, grade 420 (60); or
- b. cold drawn steel wire, ASTM A 82.

9. Epoxy Coated Reinforcing Bars. Epoxy coated reinforcing bars will be jobsite sampled in accordance with the Frequency Manual. As an alternate procedure, the reinforcing bars may be furnished by selecting bars coated from an applicator's plant on the list of Certified Reinforcing Bar Epoxy Coaters and in accordance with ITM 301. The epoxy coating material shall be selected from the list of approved Epoxy Coating for Steel.

Epoxy coated reinforcing bars shall be in accordance with ASTM A 775/A 775M, except as follows:

- a. the steel shall be in accordance with 910.01(b)1;
- b. the coating color shall contrast with the color of iron oxide;
- c. tensile and bend tests shall be performed on the bars. If an examination of the bend test specimen suggests the need, the adhesion of the coating shall be checked by subjecting additional specimens to the 120E bend test. Hairline cracks without bond loss will be acceptable provided there are not more than two and the length of either crack does not exceed 6 mm (1/4 in.). The coating thickness shall be 150 to 300 μm (6 to 12 mils) after cure. The thickness measurements shall be made in accordance with ASTM G 12. The average shall be based on 12 individual readings. No specific correction for the base preparation process shall be applied to the thickness measurements.
- d. epoxy coated reinforcing bars which will be jobsite sampled shall be accompanied by the types of certifications in the Frequency Manual and in accordance with 916. Epoxy coated reinforcing bars furnished by coaters on the list of Certified Reinforcing Bar Epoxy Coaters shall be accompanied by the types of certifications specified in ITM 301 and in accordance with 916.
- e. repair and handling procedures shall be in accordance with 703.04. The coating material shall be in accordance with the Annex to ASTM D 3963/D 3963M.

Epoxy coated support devices for epoxy coated reinforcing bars shall be in accordance with ASTM A 775/A 775M, except as follows:

- a. the steel shall be in accordance with 910.01(b)1;
- b. the coating color shall contrast with the color of iron oxide;
- c. the coating thickness shall be 150 to 300 μm (6 to 12 mils) after cure. The thickness measurements shall be made in accordance with ASTM G 12.

10. Dowel Bars. Dowel bars shall be plain billet steel in accordance with ASTM A 615/A 615M, grade 300 (40), except the bend test and elongation requirements will not apply. The dowel bar area and mass (weight) for the nominal bar diameter shall be as follows:

Nominal Bar Diameter, mm (in.)	Cross Sectional Area, mm^2 (in. ²)	Mass (Weight) kg/m (lb/ft)
25 (1)	510 (0.79)	3.973 (2.670)
32 (1 1/4)	794 (1.23)	6.209 (4.172)
33 (1 5/16)	871 (1.35)	6.846 (4.600)
38 (1 1/2)	1142 (1.77)	8.941 (6.008)

Dowel bars shall be coated with an epoxy coating material selected from the list of approved Epoxy Coating for Steel. The coating thickness after cure shall be a minimum of 175 μm (7 mils). Dowel bars shall not have burring or other deformation restricting slippage in concrete. Dowel bar ends shall be saw cut. Chips from the cutting operation shall be removed from coated bars.

Dowel bars will be jobsite sampled in accordance with the Frequency Manual and, when shipped to the project site, the bars shall be accompanied by the types of certifications specified in the Frequency Manual and in accordance with 916. As an alternate procedure, the dowel bars may be furnished by selecting bars made by a coater and manufacturer on the list of Certified Reinforcing Bar Epoxy Coaters and in accordance with ITM 301. When shipped to the project site, the dowel bars shall be accompanied by the types of certifications specified in ITM 301 and in accordance with 916.

(c) Inspection, Sampling, and Testing. All reinforcing steel may be inspected, sampled, and tested after delivery to the project.

910.02 Structural Steel.

(a) Structural Steel. Unless otherwise specified, structural steel shall be in accordance with A 709M grade 250 (ASTM A 709 grade 36).

(b) High Strength Structural Steel. This steel, when specified, shall be in accordance with ASTM A 709M grade 690 (ASTM A 709 grade 100); ASTM A 709M grade 345 (ASTM A 709, grade 50; or ASTM A 709M grade 345W (ASTM A 709 grade 50W).

The corrosion resistance of ASTM A 709M grade 345W (ASTM A 709 grade 50W) steel shall be at least four times that of structural carbon steel. The steel fabricator, when placing the order, shall state that the steel is for bridge use, and that the steel shall be used in the bare, unpainted condition.

All fasteners used in conjunction with ASTM A 709M grade 345W (ASTM A 709 grade 50W) steel shall be friction type high-strength steel bolts in accordance with ASTM A 325M (ASTM A 325) Type III. Certification and a sample shall be submitted to the Engineer prior to start of erection.

All plates and bars produced from ASTM A 572M (ASTM A 572) steel over 19 mm (3/4 in.) in thickness shall be "killed fine grain practice".

(c) Charpy V-Notch Toughness Tests. Structural steel, except members exempted below, shall meet the longitudinal Charpy V-Notch test requirement as specified in the following table for the type or types of steel specified or furnished. Sampling and testing procedures shall be in accordance with ASTM A 673M (ASTM A 673). The H frequency of heat testing shall be used. Charpy V-Notch test data shall be included on the mill test reports for structural steel specified in 711.08 and 916.

ASTM Designation	Thickness-mm (in.)	Joule (J) Foot-Pounds @ 4EC (40EF)
A 709M grade 250 (A 709 grade 36)		20.3 (15)
A 709 grade 345* (A 709 grade 50)*	Up to 100 mm mechanically fastened (4 in.) Up to 50 mm welded (2 in.)	20.3 (15) 20.3 (15)
A 709M grade 345W* (A 709 grade 50W)*	Up to 100 mm mechanically fastened (4 in.) Up to 50 mm welded (2 in.) Over 50 mm to 100 mm welded (2 in. to 4 in.)	20.3 (15) 20.3 (15) 27.1 (20)

* If the yield point of the material exceeds 450 MPa (65,000 psi), the temperature for the CVN value for acceptability shall be reduced by -10EC (15EF) for each increment of 69 MPa (10,000 psi) above 450 MPa (65,000 psi).

This test requirement shall apply to all structural steel members and/or components except diaphragms, cross frames, stiffeners, lateral bracing, railroad ballast retainers and components, shoe assemblies, expansion joints, and compression members of trusses.

(d) Mill Test Reports. Mill test reports for structural steel shall be in accordance with 711.08 and 916 and shall include Charpy-Impact test data as set out in 910.02(c).

(e) High Strength Bolts, Nuts, and Washers.

1. General Use. High strength bolts shall be in accordance with ASTM A 325M (ASTM A 325). Type 3 bolts will be required if the structural steel is to remain unpainted. High strength nuts shall be of the grade and finish specified in ASTM A 325M (ASTM A 325) and in accordance with ASTM A 563M (ASTM A 563) or ASTM A 194M (ASTM A 194). High strength washers shall be of the type specified in ASTM A 325M (ASTM A 325) and in accordance with ASTM F 436. The bolts, washers, and nuts shall be coated after fabrication in accordance with ASTM A 153, class C or AASHTO M 298, class 55.

2. Assembly of Structural Steel in Bridges. High strength bolts, nuts, and washers used in the assembly of structural steel in bridges, excluding shoes and bearing assemblies, shall be provided in accordance with 910.02(e)1 and the following additional requirements.

a. Bolts. The maximum tensile strength shall be 1034 MPa (150,000 psi) for bolts 25 mm (1 in.) or less in diameter. The maximum tensile strength shall be 827 MPa (120,000 psi) for bolts greater than 25 mm (1 in.) in diameter. The maximum hardness shall be 33 Rc.

b. Nuts. The nuts shall be in accordance with ASTM A 563M (ASTM A 563), grade DH; or ASTM A 194M (ASTM A 194), grade 2H.

c. Tests.

(1) Rotational Capacity. High Strength fasteners shall be subjected to the rotational capacity test in accordance with AASHTO M 164, Section 8.5. The fastener shall complete two times the required number of turns from snug tight conditions in accordance with AASHTO Standard Specifications for Highway Bridges, Division II, in a Skidmore-Wilhelm calibrator or equivalent tension measuring device without stripping or failure. During this test, the maximum recorded tension shall be at least 1.15 times the required fastener tension indicated in AASHTO Standard Specifications for Highway Bridges, Division II. The measured torque required to produce the required fastener tension shall not exceed the value obtained by the following equation.

$$\text{Torque} = 0.25 PD$$

Where:

Torque = Measured Torque, (newton meters) (foot-pounds)

P = Measured Bolt Tension, (newtons) (pounds)

D = Nominal Diameter (meters) (feet)

(2) Proof Loads. Proof load tests for bolts shall be conducted in accordance with ASTM F 606, Section 3.2.3. Proof load test for nuts shall be conducted in accordance with ASTM F 606, Section 4.2.

(3) Wedge Tension Test. The wedge tests of full size bolts shall be performed in accordance with ASTM F 606, Section 3.5.

270 **d. Certification.** The supplier shall provide a certification of compliance with all requirements for high strength bolts, nuts, and washers used in the assembly of structural steel in bridges, excluding shoes and bearing assemblies. The certification, in addition to complying with the applicable requirements of 916, shall include the lot number on the shipping package and indicate when or where all testing was performed.

(f) Bolts other than High Strength Bolts.

280 **1. General.** Bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A bolts of specification for low carbon steel externally and internally threaded fasteners, ASTM A 307. Bolts shall have single, self-locking nuts or double nuts unless otherwise shown on the plans or in the special provisions. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis.

Bolts, washers, and nuts utilized in the U channel steel post splice as shown on the plans shall be in accordance with ASTM A 449, SAE J429-G7.9, or ASTM A 325M (ASTM A 325) and shall be galvanized.

290 **2. Unfinished Bolts.** Unfinished bolts shall be furnished unless other types are specified.

3. Turned Bolts. The surface of the body of turned bolts shall meet the ANSI roughness rating value of 125. Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Holes for turned bolts shall be carefully reamed. Bolts furnished shall provide for a light driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut.

300 **4. Ribbed Bolts.** The body of ribbed bolts shall be of an approved form with continuous longitudinal ribs. The diameter of the body measured on a circle through the points of the ribs shall be 2 mm (5/64 in.) greater than the nominal diameter specified for the bolts. Ribbed bolts shall be furnished with round heads conforming to requirements of ANSI B 18.5 unless otherwise specified. Nuts shall be hexagonal, either recessed or with a washer of suitable thickness. Ribbed bolts shall make a driving fit with the holes. The hardness of the ribs shall be such that the ribs do not mash down enough to permit the bolts to turn in the holes during tightening. If for any reason the bolt twists before drawing tight, the hole shall be carefully reamed and
310 an over sized bolt used as a replacement.

910.03 Permanent Metal Forms. Metal bridge deck forms and supports shall be fabricated from steel in accordance with ASTM A 653M (ASTM A 653) for grades A through E having a coating class of G165 in accordance with ASTM A 525M (ASTM A 525).

320 Material furnished under this specification shall be covered by the type of certification specified in the Frequency Manual and in accordance with 916. The certification shall list the yield tensile stresses, the ultimate tensile stresses, the ultimate tensile elongations, the base metal thicknesses, the masses (weights) of the galvanized coating, and shall certify that the material complies with the specified material requirements. The properties and parameters shall be listed for each thickness (gage) of material used in the panels and the hardware necessary to erect them. The materials will be sampled at the work site and shall include a representative portion of a panel of each thickness (gage) to be used and a representative portion of each type and size of hardware necessary to erect the panels, excluding the fasteners.

910.04 Steel Forgings and Steel Shafting.

330 **(a) Carbon Steel Forgings.** Steel forgings shall be in accordance with ASTM A 668 for carbon steel forgings for general industrial use. Class F forgings shall be furnished unless otherwise specified.

(b) Cold Finished Carbon Steel Shafting. Shafting shall be in accordance with ASTM A 108 for cold finished carbon steel bars and shafting. Grade designation 1016-1030, inclusive, shall be furnished unless otherwise specified.

340 **(c) Alloy Steel Forgings.** Alloy steel forgings shall be in accordance with ASTM A 668 for alloy steel forgings for general industrial use. Class G forgings shall be furnished unless otherwise specified.

(d) Certification. Steel Forgings and Steel Shafting shall be covered by a mill certification reporting the test results of:

1. chemical analysis;
2. heat treatment, not required for shafting;
3. tensile strength, yield strength, and elongation.

350 Elongation is not required for shafting.

910.05 Castings. The casting design shall be proof loaded to 178 kN (40,000 lb) in accordance with Federal Specification RR-F-621. Castings shall be in accordance with the plan dimensions and to the following requirements for the designated materials. A certified inspection report shall be submitted by the manufacturer with each shipment of castings, except as otherwise provided herein. Inspection and testing shall be done by the manufacturer. The certified inspection report shall list the casting date, casting number, and the type of material, such as gray iron, ductile iron, etc. It shall state that inspection and testing has been performed, that all parts shipped meet the pertinent specification requirements, and that all component parts fit. The supporting test results, including proof load data, shall be retained and be available on request for a period of seven years. All castings shall have the manufacturer's identification and the date of manufacture cast on an exposed surface. Acceptance of castings will be based on the certified inspection report, visual inspection, and check measurements.

(a) Steel Castings.

1. Steel Castings for Highway Bridges. Steel castings for use in highway bridge components shall be in accordance with AASHTO M 192M (M 192), class 620 (90).

2. Chromium Alloy Steel Castings. These castings shall be in accordance with ASTM A 743M (ASTM A 743). Grade CA 15 shall be furnished unless otherwise specified.

(b) Iron Castings. Iron castings shall be gray iron castings in accordance with ASTM A 48, class No. 35B, unless otherwise specified. Tension tests will be required for all castings including drainage castings.

Castings shall be true to pattern in form and dimensions. A tolerance of " 3 mm (" 1/8 in.) in general dimensions as shown on the plans will be permitted with the exception that the tolerance in the dimensions of grates or covers and the openings into which they fit shall be limited to " 2 mm (" 1/16 in.). All castings shall weigh at least 95% of the specified mass (weight) of that type cast to the exact dimensions shown on the plans. They shall be free from sponginess, cracks, blowholes, warping, sand inclusions, cold shots, cold shuts, chilled iron shrinks, or any defects which would affect the strength and value for the intended purpose. The castings shall completely fill the molds and shall not be removed until properly cooled. The casting date and a casting code number shall be cast on each casting.

All corners of the castings shall be filleted and outside corners and edges shall be rounded to a radius of not less than 3 mm (1/8 in.). All contact surfaces between different castings shall present a firm and even bearing without rattling or rocking. The lid frame bearing surfaces on all round castings shall be machine milled to provide true bearings around the entire circumference. All other contact surfaces shall be ground.

All castings shall be cleaned of molding or core sand, rust, scale, and foreign material just prior to shipment. Iron castings shall be delivered unpainted.

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(c) Ductile Iron Castings. These castings shall be in accordance with ASTM A 536. Grade 65-45-12 shall be furnished unless otherwise specified. In addition, they shall be in accordance with all requirements of 910.05(b), except the first paragraph.

(d) Malleable Castings. Malleable castings shall be in accordance with ASTM A 47M (ASTM A 47). Grade No. 32510 or 35018 shall be furnished unless otherwise specified. In addition, they shall be in accordance with all requirements of 910.05(b), except the first paragraph.

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(e) Carbon Steel Castings. These castings shall be in accordance with of ASTM A 27M (ASTM A 27). The grade shall be 60-30, 65-35, or 70-36.

Castings shall be true to pattern in form and dimensions and free from pouring faults, sponginess, cracks, blowholes, and any defects in positions affecting their strength and value for the service intended.

Blowholes appearing on finished castings shall be located so that a straight line laid in any direction does not cut a total length of cavity greater than 25 mm (1 in.) in any 0.3 m (1 ft) nor shall any single hole exceed 25 mm (1 in.) in any dimension or have an area greater than 323 mm² (1/2 in.²). Blowholes shall not be deep enough to affect the strength of the casting adversely.

420

Minor defects which do not impair strength may, with approval, be welded by an approved process. Defects shall be removed in solid metal by chipping, drilling, or other satisfactory methods and, after welding, the castings shall be annealed if required. Castings which have been welded without permission will be rejected. No sharp unfilleted angles or corners will be allowed.

910.06 Bronze and Copper Alloy.

430

(a) Bronze Castings. Bronze castings shall be in accordance with ASTM B 22, alloys 911 or 913. Material furnished under this specification shall be covered by a type A certification in accordance with 916.

(b) Copper Alloy Plates. Copper alloy plates shall be in accordance with of ASTM B 100. Material furnished under this specification shall be covered by a type A certification in accordance with 916.

440 **910.07 Steel Drain Pipe.** Steel drain pipe may be welded or seamless, black or galvanized, and shall be in accordance ASTM A 53 except as follows:

Chemical	Furnace Butt Welded	Seamless or Electric Resistance Welded
Carbon, % max.	0.20	0.20
Manganese, % max.	1.00	1.06
Phosphorous, % max.	0.08	0.05
Sulphur, % max.	0.05	0.05
Copper, %	0.75-1.25	0.75-1.25
Nickel, %	1.60-2.20	1.60-2.20
Tensile Strength, min. MPa (psi)	379 (55,000)	448 (65,000)
Yield Point, min. psi (Pascal) Pa	276 (40,000)	317 (46,000)

The minimum elongation for furnace butt welded pipe shall be 30% in 50 mm (2 in.) for seamless pipe, in accordance with ASTM A 53, grade A, and for electric resistance welded pipe, in accordance with ASTM A 53, grade B. Material furnished under this specification shall be covered with a type C certification in accordance with 916.

450 **910.08 Blank.**

910.09 Guardrail. Guardrail of the same type shall be interchangeable regardless of the source.

460 **(a) Steel Beam Rail.** Steel beam rail shall be galvanized, corrugated, sheet steel beams in accordance with AASHTO M 180 as modified herein. The rails, including terminal sections, shall be either class A, base metal nominal thickness of 2.67 mm (0.105 in.), 12 gage, or class B, base metal nominal thickness of 3.43 mm (0.135 in.) 10 gage. They shall be type 2, zinc coated with 1.1 kg/m² (3.60 oz/sq ft) minimum single spot and 1.22 kg/m² (4.00 oz/sq ft) minimum triple spot. Tests for adherence of the coating may be made, including the test specified in ASTM A 123, when deemed necessary.

Where beam rail is set on a curve of 45.7 m (150 ft) radius or less, the rail plate shall be shop curved with its traffic face concave or convex as required. The radii of curvature shall be in increments of 3 m (10 ft) from a radius of 45.7 to 15.2 m (150 to 50 ft) inclusive and in increments of 1.5 m (5 ft) from a radius of 15.2 m (50 ft) to and including 6.1 m (20 ft).

The steel channels specified on the plans shall be standard 127 mm (5 in.) channels weighing 10.0 kg/m (6.7 lb/ft). The material shall be in accordance with ASTM A 36, (ASTM A 36). The channel shall be galvanized in accordance with ASTM A 123 after fabrication. The mass (weight) of zinc coating per area of actual surface shall average not less than 0.61 kg/m² (2.0 oz/ft²) for any individual piece of channel.

Construction details for the rails and channels shall be as shown on the plans. Whenever field fabrication, as approved, requires cutting or drilling, the cut or drilled member shall be coated with a high zinc dust zinc oxide paint in accordance with of Federal Specification TT-P-641, type II, or Military Specifications DOD-P-21035. When spray paints are used, two coats shall be applied.

(b) Aluminum Rail. Aluminum rail shall be semi-elliptical, extruded aluminum rail, in accordance with ASTM B 221M (ASTM B 221), alloy 6061-T6 or 6351-T5. Details shall be as shown on the plans. Curved rail shall be in accordance with 909.11(b).

910.10 Guardrail Posts. Guardrail posts shall be either steel, aluminum, or wood as specified and shall be in accordance with the following requirements.

(a) Steel Guardrail Posts. The dimensions of the steel guardrail posts shall be as shown on the plans. The material shall be in accordance with ASTM A 36M (ASTM A 36). The posts shall be galvanized in accordance with ASTM A 123 after fabrication. However, the mass (weight) of zinc coating per square meter (square foot) of actual surface shall not average less than 610.3 g (2.0 oz) for an individual post.

The mass (weight) of the W6 x 15 post, after fabrication and coating, shall not be less than 21.73 nor more than 23.81 kg/m (14.60 nor more than 16.00 lb/ft).

Construction details shall be as shown on the plans. Whenever field fabrication, as approved, requires cutting or drilling, the cut or drilled member shall be coated with a high zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641, Type II, or Military Specifications DOD-P-21035. When spray paints are used, two coats shall be applied.

(b) Aluminum Guardrail Posts. The aluminum guardrail posts shall be extruded aluminum, in accordance with ASTM B 221M (ASTM B 221), alloy 6061-T6 or 6351-T5. Dimensions and construction details shall be as shown on the plans.

(c) Wood Guardrail Posts. The wood guardrail posts shall be in accordance with 911.02(d). Dimensions and construction details shall be as shown on the plans.

910.11 Guardrail Accessories, Fittings, and Hardware. These items consist of brackets, splice plates and bars, post anchors, diaphragms, clamps and clamp bars, end caps, connections, anchor rod assemblies, deadmen, bolts, screws, nuts, and washers of the type, dimensions, and design shown on the plans. They shall be in accordance with the requirements set out below. Items of the same type shall be interchangeable regardless of the source.

(a) For Steel Beam Guardrail.

520

1. Post brackets, bars, plates and shapes for bridge railing brackets, and plate washers shall be in accordance with ASTM A 36M (ASTM A 36). Post brackets, bars, and plates and shapes for bridge railing brackets shall be galvanized in accordance with 910.10(a). Plate washers shall be galvanized after fabrication in accordance with ASTM A 153. The mass (weight) of the W6 x 15 post bracket shall be in accordance with 910.10(a).

530

2. Splice plates and rail portion of bridge railing brackets shall be class B, type 2, in accordance with the first paragraph of 910.09(a).

540

3. Bolts and nuts of the sizes specified on the plans shall be in accordance with ASTM A 307. Cut washers and lock washers shall be standard round steel washers of the sizes specified on the plans. The diameter of cut washers shall be 44 mm (1 3/4 in.) for 16 mm (5/8 in.) bolts and 50 mm (2 in.) for 19 mm (3/4 in.) bolts with a thickness of 3.4 mm (0.134 in.) " 0.66 mm ("0.026 in.) measured at the hole. The bolts, washers, and nuts shall be coated after fabrication in accordance with ASTM A 153, or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements for class C of ASTM A 153.

550

4. Whenever approved field fabrication requires cutting or drilling, the cut or drilled members shall be coated with a high zinc dust-zinc oxide paint conforming to Federal Specification TT-P-641, type II, or Military Specifications DOD-P21035. When spray paints are used, two coats shall be applied.
5. Pipe spacers of the size specified on the plans shall be galvanized after fabrication in accordance with ASTM A 153, class C. The mass (weight) of coating per square meter (square foot) of actual surface shall average no less than 381 g (1.25 oz) for the specimen tested and shall be no less than 305 g (1.00 oz) for any individual specimen.

6. For breakaway cable terminal, the rail element, standard bolts, nuts, and washers shall be in accordance with 910.09(a) and requirements 1 and 3 of 910.11(a).

560 High strength bolts shall be in accordance with ASTM A 325M (ASTM A 325) or ASTM A 449. High strength nuts shall be in accordance with ASTM A 563M (ASTM A 563), Grade B or better. Galvanizing shall be in accordance with ASTM A 153 or mechanically galvanized and conform to the coating thickness, adherence, and quality requirements for class C of ASTM A 153. Foundation plates and bearing plate shall be in accordance with ASTM A 36M (ASTM A36), and shall be galvanized after fabrication in accordance with ASTM A 123, except the mass (weight) of zinc coating per square meter (square foot) of actual surface shall average no less than 610 g (2.0 oz) and shall be no less than 549 g (1.8 oz) for any individual specimen. Welding shall be in accordance with AWS D1.1.

570 Terminal posts shall be fabricated from tubing meeting ASTM A 500, Grade B, or ASTM A 501 and from plates meeting ASTM A 36M (ASTM A 36). Welding shall be in accordance with AWS D1.1. They shall be galvanized after fabrication in accordance with ASTM A 123, except the mass (weight) of zinc coating per square meter (square yard) of actual surface shall average no less than 610 g (2.0 oz). The average for any component part, including paddle plate, tubing, or base plate, shall be no less than 549 g (1.8 oz).

580 The steel pipe in the type 5 anchor and the steel spacer tube in the transition type WGB shall be Schedule 40.

Tapered washers may be of steel or malleable iron, and galvanized in accordance with ASTM A 153.

The steel pipe in the type 5 anchor and the steel spacer tube in the transition type WGB shall be Schedule 40.

590 The wire rope used in the cable assembly shall be in accordance with AASHTO M 30 and shall be 19 mm (3/4 in.) preformed, 6 by 9, wire strand core or independent wire rope core (IWRC), galvanized, right regular lay, manufactured of improved plow steel, with a minimum specified breaking strength of 190 kN (42,800 lb). The swaged fitting, stud, and nut shall develop the breaking strength of the wire rope. The fitting shall be galvanized in accordance with ASTM A 123 before swaging. After galvanizing, the head and nut may be tapped 0.6 mm (0.023 in.) over the ANSI B1.1, class 2B tolerance.

(b) For Aluminum Guardrail.

- 600
1. Splice bars, clamp bars, diaphragms, and brackets shall be aluminum in accordance with ASTM B 221M (ASTM B 221), alloy 6061-T6 or 6351-T5.
 2. Washers shall be aluminum in accordance with ASTM B 209M (ASTM B 209), alloy Alclad 2024-T4 or stainless steel in accordance with ASTM A 276, type 430.
 3. Anchor bolts, bracket bolts, cap screws, and nuts shall be stainless steel in accordance with ASTM A 276, type 304 or 430.
- 610
4. Rail end caps shall be aluminum alloy A356.0 in accordance with ASTM B 26M (ASTM B 26) or ASTM B 108.
 5. Terminal pieces shall be aluminum in accordance with ASTM B 108, alloy A356.0.
 6. All aluminum surfaces in contact with concrete shall be given one shop coat of zinc chromate paint.

(c) For Steel Tube Guardrail.

- 620
1. Channels and bars for connections, splice bars, and diaphragms shall be in accordance with ASTM A 36 (ASTM A 36).
 2. Cap screws shall be stainless steel in accordance with ASTM A 276, type 304 or 430.
 3. Rail end caps shall be malleable iron castings in accordance with ASTM A 47M (ASTM A 47), grade 35018, or steel castings in accordance with ASTM A 27M (ASTM A 27), grade 70-36.
- 630
4. Cut washers and lock washers shall be standard round steel washers. The diameter of cut washers shall be 37.5 mm (1 1/2 in.) and 3.2 mm (1/8 in.) thick measured at the hole. Washers shall be coated after fabrication in accordance with requirement 3 of 909.11(a).
 5. All materials other than cap screws and washers shall be galvanized after fabrication in accordance with ASTM A 123.

- 640
6. When field fabrication, as approved, requires cutting or drilling, the cut or drilled members shall be coated with a high zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641 type II or Military Specifications DOD-P-21035. When spray paints are used, two coats shall be applied.

910.12 Samples and Certification of Guardrail, Posts, Accessories, Fittings, and Hardware. All samples required for testing purposes shall be furnished free of charge. General requirements for sampling are as follows:

650 **(a) Control Procedure for Furnishing Steel Beam Guardrail and Accessories.**
All steel beam guardrail and accessories shall be subject to one of the two control procedures as follows:

1. installers on a certification basis with random in place testing of guardrail;
2. installers not qualifying or not desiring certification basis with job control sampling.

660 Installers desiring to be on certification status will be approved upon request. The request need not be in writing, but it shall be requested through the Division of Materials and Tests. A 6-digit approval number will be assigned to each installer to be used for identification acceptability of material.

The installer shall perform testing or shall obtain documentation to ensure the quality of the material incorporated into the work.

670 The installer shall prepare and attach to each monthly material record a certification in accordance with 916.02(d). Such certification shall contain the contract number; installer's name; installer's approval number; month of installation; rail manufacturer; bolt manufacturer; quantities of rail, channel, posts, block, and paddle posts incorporated into the work; quantities of sawed timber posts and blocks for thrie-beam and W-beam guardrail incorporated into the work; and a notarized statement sworn by a person having legal authority to bind the company preparing the certification that the materials furnished are in accordance with 910.09 through 910.12.

680 The Department will inspect the steel beam guardrail on a randomly selected contract for compliance with specifications for a minimum of one time per year per installer. The inspections will be performed before the contract is certified by the Division of Materials and Tests. Various dimensional checks, various coating thickness determinations, proper identification checks for rail and bolts, bore cores for determination of preservative retention, and penetration for sawed timber posts and blocks for end sections will be performed.

Randomly selected contracts with failing results will be issued a Failed Materials Report. Failed materials will be subject to action by the Failed Materials Committee.

690 If the installer shows negligence or the inability to ensure the delivery of specified materials, the installer's immediate usage status may be removed.

Suppliers not desiring to retain their certification or who lose status will have their material sampled at the project site after delivery. No material may be used until it has been tested and approved.

Samples will be obtained from materials after delivery to the jobsite or while being held in inventory at the Contractor's yard, if it is located in an area normally serviced by the Department.

700 **(b) Aluminum Guardrail.** Rails, posts, accessories, fittings, and hardware will be accepted based on a visual inspection confirming the physical dimensions conform to the requirements as shown on the plans and a type C certification in accordance with 916.

910.13 Steel Fence Posts. Tubular steel fence posts and line posts shall meet the following specifications and the requirements as shown on the plans.

710 All posts except tubular steel fence posts shall be galvanized in accordance with ASTM A 123, except the mass (weight) of the coating per square meter (square foot) of actual surface on anchor plates attached to posts shall average no less than 458 g (1.50 oz) and shall be no less than 382 g (1.25 oz) for any individual specimen. Posts and anchor plates for line posts shall be of good commercial quality steel and of the shapes, weights, and dimensions shown on the plans.

Line posts for farm field fence shall be furnished with anchor plates. End, corner, pull, and gate posts for farm field type fence shall be furnished with braces and all fittings and details required to make a complete installation as shown on the plans.

720 **(a) Tubular Steel Fence Posts.** Two groups of tubular steel fence posts are included in these specifications. Tubular section posts shall have heavy malleable iron caps or pressed galvanized steel caps. Such caps shall be made to provide a drive fit over the outside of the section to exclude moisture. The mass (weight) per meter (foot) for tubular posts and braces shall be no less than 90% of the mass (weight) specified. Unless specified otherwise, the tubular steel fence post shall be group 1.

730 **1. Group 1.** Tubular steel fence posts for group I shall be hot-dipped zinc-coated and shall be in accordance with ASTM F 1083 except tests shall be conducted on sample posts selected as being representative of the posts furnished. The mass (weight) per meter (foot) will be acceptable provided it is at least 90% of the specified mass (weight).

2. Group 2. Tubular steel fence posts for group 2 shall have a minimum 345 MPa (50 ksi) yield strength and be in accordance with AASHTO M 181, except that the inner pipe surface may be galvanized in lieu of a zinc rich coating or hot dipped aluminum coated, Type 2, meeting the chemical requirements of AASHTO M 274. The aluminum coated, Type 2, steel fence posts shall be manufactured by roll forming aluminum coated, Type 2, steel strip and electric resistance welding it into tubular form. The outside of the weld area shall be metallized with commercially pure aluminum to a thickness sufficient to provide resistance to corrosion equal to that of the remainder of the outside of the post. The aluminum coating mass (weight) shall be a minimum of 229 g/m² (0.75 oz/sq ft) average, and 214 g/m² (0.70 oz/sq ft) for an individual test specimen, as measured in accordance with ASTM A 428. Specimens for determining weight of coating shall be obtained in accordance with ASTM F 1083.

(b) Fence Fastenings. When fastenings are necessary for attaching the farm field fence to the posts, they shall be either galvanized or aluminum coated 3.8 mm (No. 9) wire, or galvanized or aluminum coated clamps of the manufacturer's standard design. The coating weights shall be a minimum of 183 g/m² and 92 g/m² (0.60 oz/sq ft and 0.30 oz/sq ft) for galvanized and aluminum coated, respectively. A sufficient quantity of individual tie wires or clamps shall be furnished to provide for five attachments of the fencing to each line post and one tie wire for each strand of barbed or tension wire.

Line posts for chain link type fence shall be furnished with the necessary tie wires or fabric bands for fastening the fabric to the posts. These fastenings shall be made of aluminum strip or wire of approved gage and design or of galvanized steel wire and may be in accordance with the manufacturer's standard design. If galvanized steel wire ties are furnished, the wire shall be no smaller than No. 9 gage (3.8 mm). A sufficient quantity of individual ties or bands shall be furnished to provide for attaching the fabric to each line post each 0.3 m (1 ft) or as called for on the plans.

910.14 Sign Posts.

(a) Steel, Flanged, Channel Posts.

1. General Requirements. Posts shall be made from open hearth, basic oxygen, or electric furnace steel rolled from standard tee rails or new billets. The steel used in the posts shall conform to the physical properties of ASTM A 499, grade 60, and to the chemical composition of ASTM A 1 for 45 kg/m (91 lb/yd) or larger steel rails.

Posts fabricated from other steels will be acceptable providing that the following criteria are met. A notarized copy of a dynamic crash test report shall be furnished substantiating that the posts manufactured from this material, when double mounted in a 2.1 m (7 ft) span, conform to the breakaway requirements of AASHTO, Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, except that the maximum change in velocity shall not exceed 4.9 m/s (16 ft/s). For two posts in a 2.1 m (7 ft) path, impact performance may be estimated by multiplying the vehicle energy loss observed in a single post crash test by 2. This estimated double post energy loss may then be used to calculate an estimated impact velocity change and momentum change for a double post sign design. The minimum yield strength shall be 414 MPa (60,000 psi) and the minimum tensile strength shall be 621 MPa (90,000 psi).

The tensile strength shall be determined by either the standard Rockwell Hardness test, Brinell Hardness test, or by actual tensile test. The Rockwell Hardness shall be a minimum of B 91. The yield strength shall be determined by the manufacturer by actual test. Tensile and yield strengths and chemical composition shall be determined by the average from the three latest test results the manufacturer has available at the time of shipment. These test results need not be made on the materials from which the posts were made. However, the tests must have been made within 90 days of shipment. Posts shall be certified by a type B certification in accordance with 916. The certification shall include the above three test results and the elastic section modulus value in accordance with 910.14(a)3.

Posts shall be of uniform flanged channel or U section such that the area of contact between the post and the sign is symmetrical about the vertical axis of both sign and post. The back of each post shall be formed in a manner to ensure a solid bearing surface over the entire length of the post when mounted back to back. The bearing surface on the back of the post shall be flat. The length shall be as specified with a tolerance of ± 25 mm (± 1 in.). Sign posts shall be punched with 58 holes which shall be 9.5 mm (3/8 in.) in diameter located on the center-line and spaced on 25 mm (1 in.) centers beginning 25 mm (1 in.) from the top. The remainder of the post shall be punched with 9.5 mm (3/8 in.) holes on 25 mm (1 in.) or 50 mm (2 in.) centers.

The finished posts shall be machine straightened and have a smooth uniform finish free from cracks, flaws, injurious seams, laps, blisters, and edges which are ragged, sharp, and imperfect, or other defects affecting their strength, durability, or appearance. The maximum variation in straightness shall be no more than 6 mm (1/4 in.) in any 1.5 m (5 ft) of length, or exceed in millimeters (inches) 1/4 times the number of meter (feet) of length divided by five. Bolt holes of the diameter specified shall be accurately spaced vertically and centered horizontally so that holes will register for back to back application. All holes and sheared ends shall be commercially free from burrs.

The steel sign posts shall be galvanized in accordance with ASTM A 123.

Galvanizing shall be the final process after all fabrication and punching has been completed. Posts saw cut after galvanizing shall have the cut surface treated with a zinc-based solder in rod form which complies with ASTM A 780. The cut surface shall not be treated until the fuse plate is installed and all bolts are tightened. The top of the fuse plate shall be 25 mm (1 in.) below the bottom of the sign.

Posts saw cut before galvanizing shall have temporary fasteners provided with sufficient strength to prevent warping or deforming of the post during the galvanization process. The surface under the temporary fasteners shall be treated with an approved zinc solder meeting the above mentioned specification. The surface shall be treated before the fuse plate is installed. The break-away stubs shall be galvanized a minimum of 200 mm (8 in.) below the top of the concrete foundation.

Steel posts shall be wired or strapped securely in bundles of not more than 907 kg (2,000 lb). They shall be nested in rows with the edges intermeshed so as to form a rectangular bundle and shall be fastened in such a manner that they do not slip or rub against each other and cause damage to the finish. Care shall be taken during shipment to prevent the bundles from rubbing against each other and causing damage. Excessive damage to the finish during shipment will be cause for rejection of the damaged posts.

2. Deflection Test Requirements. Posts will be tested as a simple beam with the flanges in compression on non-restricting supports 610 mm (24 in.) apart. Test specimens shall be 711 mm " 6.3 mm (28 in. " 1/4 in.) long. A load of 6672, 15569, 20462 N (1,500, 3,500 or 4,600 lb), depending on the type of post, shall be applied at the center of the span with a mandrel of not less than 25 mm (1 in.) in diameter. Application of the load shall be at a speed not to exceed 8 mm (0.3 in.) per min. Deflection of the post upon application of the total load shall not exceed 4 mm (0.16 in.). The load shall then be removed. Deflection of the post one minute after removal of the load shall not exceed 0.25 mm (0.01 in.).

3. Type of Posts. Posts shall conform to the following table and to deflection tests required in 910.14(a)2.

Type	Minimum Elastic Section Modulus	Loading
A	.200	6672 N (1,500 lb)
B	.400	15569 N (3,500 lb)
C	.560	20462 N (4,600 lb)
Abb*	.670	**
Bbb*	1.190	**

* Back to Back

** Back to back posts shall be tested singly for deflection prior to assembly.

Note: The elastic section modulus values shall be included in the type B certification.

(b) Wide Flange Posts. Structural steel members for the support of signs shall be in accordance with AASHTO M 183 and ASTM A 709M grade 250 (ASTM A 709 grade 36). These members shall be galvanized in accordance with ASTM A 123. Base plates and stiffeners shall be in accordance with the requirements of ASTM A 709M grade 250 (ASTM A 709 grade 36). Fuse plates shall be in accordance with the requirements of ASTM A 36M (ASTM A 36) and shall be galvanized in accordance with ASTM A 123. All bolts, nuts, and washers shall be high strength and be in accordance with AASHTO M 164 and ASTM A 325.

All holes shall be drilled. All cutting shall preferably be saw cuts however flame cuts as specified in 711.13 may be allowed. Metal projecting beyond the plane of the plate face will not be allowed.

(c) Structural Steel Posts. Steel members for the support of signs shall be standard shapes as specified and shall be in accordance with 910.02(a). These members shall be galvanized in accordance with ASTM A 123. Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(d) Structural Aluminum Posts. These posts shall be standard shapes as specified and shall be aluminum in accordance with ASTM B 221M (ASTM B 221) alloy 6061-T6. Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(e) Square Steel Posts. Square steel sign post shall be covered by the type of certification specified in the Frequency Manual and in accordance with 916.

1. Steel. Square steel posts shall be roll formed and in accordance with one of the following:

- a. ASTM A 570, hot rolled carbon sheet steel in either 2.66 mm (0.105 in.) or 1.90 mm (0.075 in.) with a minimum yield strength of 414 MPa (60,000 psi). The ultimate tensile strength shall not exceed 550 MPa (79,800 psi) or have an elongation measured over 50 mm (2 in.) greater than 20%.
- b. ASTM A 715, cold rolled high strength steel, 1.90 mm (0.075 in.) with a minimum yield strength of 414 MPa (60,000 psi). This shall apply to the 50 mm x 50 mm (2 in. x 2 in.) size posts only.
- c. ASTM A 653, cold rolled high strength steel, 1.90 mm (0.75 in.) with minimum yield strength of 414 MPa (60,000 psi). The ultimate tensile strength shall not exceed 550 MPa (79,800 psi) or have an elongation measured over 50 mm (2 in.) greater than 20%. This requirement shall apply to the 50 mm x 50 mm (2 in. x 2 in.) size posts only.

Yield strengths and chemical composition shall be determined from the three latest test results performed by the steel manufacturer. These test results may not be determined on materials from which the delivered posts were made. However, the tests shall have been performed within 90 days of shipment. The certification shall include the range of test results and the section modulus value in accordance with 910.14(a)3.

2. Fabrication. The posts shall be corner welded and scarfed as necessary to allow sections to telescope within each other. The finished posts shall be machine straightened and have a smooth uniform finish free from cracks, flaws, injurious seams, laps, blisters, and edges which are ragged, sharp, and imperfect, or other defects affecting their strength, durability, or appearance. The maximum variation in straightness shall be no more than 6.3 mm (1/4 in.) in any 1.52 m (5 ft.) of length. Cut holes or knockout holes of 11 mm (7/16 in.) diameter shall be spaced on 25 mm (1 in.) centers, on the centerlines of all four sides in true alignment, and opposite to each other for back to back applications. All holes and sheared ends shall be free from burrs.

3. Protective Coating. The protective coating shall be applied using one of the following:

- a. Before fabrication, both sides of the rolled sheet steel shall be galvanized in accordance with ASTM A 653M, coating designation Z 275 (ASTM A 653, coating designation G 90).
- b. After fabrication, a triple coating system on the outside of the posts consisting of galvanizing with zinc which is in accordance with AASHTO M 120 weighing $183 \pm 46 \text{ g/m}^2$ (0.60 " 0.15 oz/ft²) followed by a chromate conversion coating weighing $0.02 \pm 0.006 \text{ g/m}^2$ (15 " 5 micrograms Fg/in.²) and a clear organic exterior coating with a dry film thickness of $5 \pm 2.5 \text{ }\mu\text{m}$ (0.2 " 0.1 mil). The interior surface of the posts shall receive a double in-line application of a zinc rich organic coating with a total dry film thickness of $30 \pm 15 \text{ }\mu\text{m}$ (1.2 " 0.6 mil). The dried zinc rich organic coating film shall contain a minimum of 77% total zinc. Samples from the posts which use these protective coatings shall be exposed to salt fog testing in accordance with ASTM B 117 for a total of 500 h. The samples shall be examined at both 100 and 500 h of salt fog testing and rated for corrosion. At 100 h the corrosion rating shall be a minimum of 9 and at 500 h the corrosion rating shall be a minimum of 6 when determined in accordance with ASTM D 1654.

(f) Portable Construction Sign Trailer. The portable construction sign trailer, not including the signs and lights, shall weigh no more than 140 kg (300 lb) and shall not be fabricated with heavier than 75 x 75 mm (3 x 3 in.) angles, 63 mm (2 ½ in.) pipe, or 75 x 50 mm (3 x 2 in.) rectangular tubing. The rim size of the wheels shall not exceed 300 mm (12 in.). Axle assemblies with differential housings shall not be used.

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910.15 Delineator Posts. Posts shall be made from open hearth, basic oxygen, or electric furnace steel rolled from new billets or standard tee rails and have the mechanical and chemical properties set out for sign post in 910.14(a)1. The post shall be a uniform, modified, flanged channel or U section such that the area of contact between the post and reflector is symmetrical with the vertical axis of both reflector and post.

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Physical requirements for steel delineator posts shall be: width of flange face 50 mm to 60 mm (2 to 2 3/8 in.); width of back 19 mm to 22 mm (3/4 to 7/8 in.); depth from face of flange to back 22 to 29 mm (7/8 to 1 1/8 in.); length 2.1 m " 25 mm (7.0 ft " 1 in.). Mass (Weight) of the finished post shall be not less than 1.5 nor more than 2.2 kg/m (1.0 nor more than 1.5 lb/ft).

Delineator posts shall be punched with a minimum of twenty-four 6 mm (1/4 in.) holes on the centerline spaced on 25 mm (1 in.) centers beginning 25 mm (1 in.) from the top. The finish, straightness, and coating of the delineator posts shall be in accordance with the applicable requirements of 910.14(a)1. Post with 9.5 mm (3/8 in.) holes may be used on contracts let prior to January 1, 1992.

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910.16 Copper Flashing. Copper flashing shall be soft copper and shall be in accordance with ASTM B 370, except the minimum copper content shall be 99.5%. The mass (weight) per square meter (square foot) will be determined by weighing individual samples. If the first sample is not in accordance with the tolerances for 450 g (16 oz) sheet, two additional samples shall be tested and both shall comply with the specified tolerances. The sample shall withstand being bent cold through an angle of 180 degrees flat upon itself, without failure of the outside of the bent portion. The type of certification for copper flashing will be covered by the Frequency Manual and shall be in accordance with 916.

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910.17 Bronze or Copper Alloy Plates. Bronze or copper alloy to be used for self lubricating bearing plates shall conform to one of the following requirements based on the design unit loading set out on the detail plans.

Design Unit Loading not over	Shall Conform to ASTM
A. 3000 psi (20684271 Pa)	B 22, Alloy C86300
B. 2500 psi (17236894 Pa)	B 100, Alloy C51000
C. 2000 psi (13789514 Pa)	B 22, Alloy C91100
D. 1000 psi (6894757 Pa)	B 22, Alloy C90500*

* Up to 2.5% lead allowed.

The sliding surfaces of the plates shall be provided with cylindrical recesses with a depth necessary to provide proper containment of the lubricant. The recesses shall be arranged in a geometric pattern so that each successive row will overlap in the direction of motion. The total area of the recesses shall comprise no less than 25% and no more than 35% of the total area of the plate.

The surface finish of bearing areas shall be in accordance with ANSI B46.1 #125. The lay of tool marks shall be in the direction of expansion or contraction of the structure. If the surface is ground, grinding knurls may be omni-directional. Flat bearing surfaces shall be flat to a tolerance of " 0.0125 mm (0.0005 in.). Curved bearing surfaces shall be machined to a tolerance of " 0.0005 of an inch (0.0125 mm) in each 25 mm (1 in.) of length perpendicular to the circular section. The radius of curved bearing surfaces shall have the following tolerances:

	Positive Tolerance	Negative Tolerance
Concave Surface	0.25 mm (0.010 in.)	0.000 mm (0.000 in.)
Convex Surface	0.000 mm 0.000 in.	0.25 mm (0.010 in.)

The lubricant shall be of the solid type. It shall consist of graphite and metallic substances having lubricating properties with a lubricating binder. The lubricant shall be free of any material that causes abrasive or corrosive action on the metal surfaces. It shall withstand the atmospheric elements. The lubricant shall be compressed into the recesses of the bearing plate by hydraulic pressure to form a dense non-plastic lubricating insert.

At the time of assembly in place, the steel surfaces which bear on the self lubricating bearing plate shall be lubricated with additional lubricant furnished by the manufacturer. White lead, tallow, or other coating shall be removed before the application of the lubricant.

The coefficient of friction between the self lubricating plate and the steel plates in contact with them shall not exceed 0.10 when subjected to twice the designed loading.

Material furnished under this specification shall be covered by a type C certification in accordance with 916.

910.18 Fence, Fittings, and Gates.

(a) Farm Field or Woven Wire Fence. This fence shall be in accordance with ASTM A 116. The wire shall be 3.8 mm (No. 9 gage). The design shall be 1047-6-9. The coating shall be class 3. The method of securing the vertical stays to the horizontal wires may be either of those shown on the plans. Diagonal braces shall be in accordance with 910.18(b)3.

1030 **(b) Steel Fabric Chain Link Fence.** This fence shall be in accordance with ASTM A 392 for galvanized steel fabric or ASTM A 491 for aluminum coated steel fabric. The height of the fabric shall be 1.22 m (48 in.) unless otherwise specified. It shall be of 3.8 mm (No. 9 gage) wire woven in 50 mm (2 in.) mesh. The fabric shall be knuckled at the top and bottom selvages when the height is less than 1830 mm (72 in.). Fabric of 1830 mm (72 in.) in height or higher shall be knuckled at the top and shall have the twisted and barbed finish at the bottom. For galvanized fabric, coating shall be done after weaving and shall be class II, average of 2 or more specimens no less than 610 g/m² (2.0 oz/sq ft) and no less than 549 g/sq m² (1.8 oz/sq ft) for any individual specimen. For aluminum coated fabric, coating shall be class II, 122 g/m² (0.40 oz/sq ft) minimum.

1040 The fabric shall be furnished with ties required for fastening it to the top and bottom tension wires. These fastenings may be of aluminum wire or strip of approved gage and design, or of galvanized steel wire in accordance with the manufacturer's standard design. If galvanized steel wire ties are furnished, the wire shall be no smaller than 2.7 mm (No. 12 gage). Sufficient ties shall be furnished to provide for attaching to the top and bottom tension wires each 600 mm (24 in.). Fittings necessary to make complete installation shall be pressed or rolled steel, forged steel, cast steel, or malleable iron.

1050 Steel fabric chain link fence shall be as shown on the plans and as set out above. Twisted and barbed finish shall not be used on both the top and bottom of fabric after January 1, 1996.

1060 **1. Tension Wire.** Tension wire intended for use on the top or bottom of steel chain link fence or on the bottom of farm field fence when specified shall be spring coil or crimped steel wire with an initial diameter of 0.177 " 4.5 " 0.1 mm), a minimum breaking load of 8.67 kN (1,950 lb), and a coating of either zinc or aluminum. The minimum mass (weight) of coating shall be 244 g/m² (0.80 oz/sq ft) for galvanized wire and 122 g/m² (0.40 oz/sq ft) for aluminum coated steel wire. The mass (weight) of aluminum coating shall be determined in accordance with ASTM A 428.

1060 **2. Stretcher Bars, Truss Rods, and Turnbuckles.** Stretcher bars shall be 4.8 x 19.0 mm (3/16 by 3/4 in.) flat bars. These bars, truss rods, turnbuckles, and necessary fittings shall be of good commercial quality steel, malleable iron, or wrought iron. They shall be galvanized in accordance with ASTM A 153 after fabrication. The turnbuckles shall be made from drop forged malleable iron. They shall have a minimum take up of 100 mm (4 in.). The fittings may be pressed or rolled steel, forged steel, cast steel, or malleable iron.

1070 **3. Braces.** Braces shall be made of steel pipe with bolted steel couplings or connections. Steel pipe shall be in accordance with ASTM F 1083. They shall be galvanized as set out therein. Fabrication or manipulation that causes minor damage to the galvanized coating shall be corrected by approved application of a high zinc dust-zinc oxide paint conforming to the requirements of Federal Specification TT-P-641 type II or Military Specifications DOD-P-21035. When spray paints are used, two coats shall be applied. Damaged braces will be rejected.

1080 **4. Barbed Wire.** Barbed wire used at the top and bottom of farm field fence, or as otherwise specified, and in accordance with 603 shall be in accordance with applicable provisions of ASTM A 121. It shall be composed of 2.5 mm (No. 12 1/2 gage) galvanized or aluminum coated steel wire with four round 2.0 mm (14 gage) barbs at approximately 125 mm (5 in.) spacing. The galvanized coating shall be in accordance with class 3 in Table 3. The minimum aluminum coating mass (weights) shall be 91.5 and 76.3 g/m² (0.30 and 0.25 oz/sq ft) on the 2.5 mm (12 1/2 gage) wire and 2.0 mm (14 gage) barbs respectively. The mass (weight) of coating shall be determined in accordance with ASTM A 428. The use of aluminum barbs, in accordance with ASTM B 211M (ASTM B 211), alloy 5052-H38, nominal diameter 2.0 mm (0.080 in.), will be permitted.

1090 The use of barbed wire with 1.7 mm (No. 15 1/2 gage), high tensile strength line wires, and 1.5 mm (No. 16 1/2 gage) barbs will be permitted. The barbs shall be round with four points and spaced at approximately 125 mm (5 in.) intervals. The barbed wire shall be in accordance with ASTM A 121, except the minimum mass (weight) of zinc coating shall be 229.0 g/m² (0.75 oz/sq ft) for line wires and 214.0 g/m² (0.70 oz/sq ft) for barbs.

1100 **(c) Aluminum Fabric Chain Link Fence.** This fence shall be in accordance with the applicable requirements of 910.18(b) except for composition of materials. Requirements for the various component parts of aluminum fence shall be as shown in Table 1.

TABLE 1

ITEM	ASTM REFERENCE	ALLOY	ADDITIONAL INFORMATION
Fabric	B 211M (B 211)	Alclad 5056 or 6061-T94	
Barbed Wire - Line	B 211M (B 211)	5062-0, H38 or 6061-T89	2-strand dia. 2.8 mm (0.110 in.) 4-pt. barb. dia. 2.0 mm (0.080 in.) 127.0 mm (5 in.) space
Barbs	B 211M (B 211)	5052-H38	
Tension Wire	B 211M (B 211)	Alclad 5056 or 6061-T94	Dia. 4.9 mm (0.192 in.); Note 1
Hog Ring Fasteners	B 211M (B 211)	6061-T94	Dia 2.8 mm (0.110 in.)
Wire Ties	B 211M (B 211)	1100-H18	Dia. 3.8 mm (0.148 in.)
Flat band ties	B 211M (B 211)	3003-H14	12.7 mm (1.2 in.) wide; 1.5 mm (0.06 in.) thick
Stretcher Bars	B 211M (B 211)	6063-T6	19.0 mm (3/4 in.) by 6.4 mm (1/4 in.); square edges
Truss and Brace Rods	B 211M (B 211) or B 221M (B 221)	6061-T6	Dia. 9.5 mm (3/8 in.)
Turn Buckles	B 26M (B 26) (cast parts), B 211M (B 211) (wrought)	356.0-T6 6061-T6	
Bands	B 221M (B 221)	6063-T6	3.2 mm (1/8 in.) by 25 mm (1 in.) beveled edge
Bolts	B 211M (B 211) or B 221M (B 221)	2024-T4	ASA B18.2 hexagon threads class 2, 2A, or 2B
Nuts	B 211M (B 211) or B 221M (B 221)	6061-T6	
Expansion Sleeves	B 210M (B 210)	3003-H18	43.1 mm (1.695 in.) ID by 1.98 mm (0.078 in.); wall drawn type. 152 mm (6 in.) long; self centering
Post Tops, Rails And Brace Ends	B 26M (B 26) or B 108	356.0T6	Fabricated in permanent molds or sand castings
Top and Brace Rails	B 241M (B 241) and B 429	6063-T6	31.8 mm (1 1/4 in.) pipe; Note 2
Barbed Wire Extension Arms	B 26M (B 26) or B 108	356.0T6	Fabricated as for post tops; sheet castings
Line Posts	B 241M (B 241) and B 429	6063-T6	50 mm (2 in.) pipe; Note 2
Corner Posts	B 241M (B 241) and B 429	6063-T6	63 mm (2 1/2 in.) pipe; Note 2

Note 1: Aluminum coated steel wire in accordance with 910.18(b) may be used.

Note 2: ANSI schedule 40 pipe, plain ends.

(d) Gates. Gate post sizes shall be as follows:

ANSI Nominal Pipe Size	Swing Gate Opening, (inclusive)	
	Single Gate	Double Gate
64 mm (2 1/2 in.)	up to 1.83 m (6 ft)	up to 3.66 m (12 ft)
89 mm (3 1/2 in.)	2.13 m to 3.96 m (7 to 13 ft)	3.96 m to 7.92 m (13 to 26 ft)
152 mm (6 in.)	4.27 m to 5.49 m (14 to 18 ft)	8.23 m to 11.28 m (27 to 36 ft)
203 mm (8 in.)	5.79 m to 9.75 m (19 to 32 ft)	11.27 m to 19.51 m (37 to 64 ft)

1110 **1. Steel Gates.** Steel gate posts shall be standard weight, galvanized, steel pipe in accordance with ASTM F 1083 and furnished with all necessary fittings. Post sizes shall be as set out above. The gate frames shall be of standard mass (weight), galvanized, steel pipe in accordance with ASTM A 120; of 38.1 mm (1 1/2 in.) nominal size; and shall have welded joint or riveted construction using galvanized pressed steel or malleable fittings. Areas welded after galvanizing shall be coated with a material conforming to the requirements of Federal Specification TT-P-641, type II, or Military Specification DOD-P-21035. When spray paints are used, two coats shall be applied. Fabric coverings for gates shall be in accordance with 910.18(a) or 910.18(b). These gates shall be furnished with necessary fastenings, hinges, center stops, and locking devices galvanized after fabrication in accordance with ASTM A 153.

1120 **2. Aluminum Gates.** Aluminum gate post sizes shall be in accordance with 910.18(d). They shall be ANSI schedule 40 pipe and in accordance with ASTM B 241M (ASTM B 241) or B 429, alloy 6063-T6. Gate frames shall consist of 38 mm (1 1/2 in.) schedule 40 pipe assembled by welding and/or with fittings. Pipe shall be in accordance with ASTM B 241M (ASTM B 241) or B 429, alloy 6063T6. Welding material and procedures shall be in accordance with the applicable AWS provisions. Formed sheet fittings shall be in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. Gate hinges may be offset type wrought aluminum, ASTM B 209M (ASTM B 209), alloy 6061-T6, or galvanized malleable iron. Fabric shall be in accordance with 910.18(c).

1130 **(e) Control Procedures for Furnishing Fence and Accessories.**

1. General Requirements. All fence and accessory materials shall be subject to the control procedures set out herein. The control procedure methods which may be used are as follows:

- a. Suppliers qualified to furnish pretested approved stockpiled material.

Strain poles for cable span signs shall be in accordance with 913.15(e)1. Each strain pole shall include three band type attachments for span wire clamps. Such attachments shall be galvanized in accordance with ASTM A 153. Cable shall be in accordance with 913.15(f)2. Each cable shall include three wire rope clips at each end. Anchor bolts shall be in accordance with 913.15(e)1a. All sign mounting hardware except for the extruded aluminum bar shall be galvanized in accordance with ASTM A 153.

1190 Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(a) Aluminum Overhead Sign Structures, Box Truss and Bridge Attached.

Extruded tubes shall be of aluminum in accordance with ASTM B 221M (ASTM B 221), B 241M (B 241), or B 429, alloy 6061-T6. Anchor base castings shall be of aluminum in accordance with ASTM B 26M (ASTM B 26) or B 108, alloy 356.0-T6. All other castings shall be of aluminum in accordance with ASTM B 26M (ASTM B 26), alloy 356.0-T6. Plates shall be aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. Plates shall be free of sharp edges and irregularities.

1200 Welding material and procedures shall be in accordance with applicable AWS provisions.

Bolts, nuts, screws, and flat washers shall be passivated type 304 stainless steel. Bolts and screws shall be in accordance with ASTM A 193M (ASTM A 193), grade B8. Hexagon nuts and washers shall be in accordance with ASTM A 194M (ASTM A 194), grade 8.

1210 Anchor bolts shall be in accordance with ASTM A 307. A hexagon nut, leveling nut, and flat washer in accordance with ASTM A 307, grade A, shall be furnished with each anchor bolt. Threaded ends of anchor bolts and associated hardware shall be coated in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

1220 Certified proof of the qualifications for a minimum of two welders shall be presented after the contract is awarded and before fabrication is started. This certification shall be from a commercial or public testing laboratory and qualifications shall be based on welding of aluminum alloy, 6061-T6 with consumable electrode type welding using aluminum alloy ER4043 filler material. Welders shall qualify by passing the requirements of "Procedure and Performance Tests of Qualification Standard for Welding Procedures, Welders, and Welding Operations," latest edition, formulated by the Boiler and Pressure Vessel Committee of the American Society of Mechanical Engineers.

Welding shall be checked carefully by visual inspection. Poor welding workmanship as noted by visual inspection shall be sufficient cause for rejection.

Each complete structure shall be warranted that it is free from any misfits or structural deficiencies prior to shipment.

1230 **(b) Steel Overhead Sign Structures, Box Truss, Cantilever, Monotube, and Bridge Attached.** Steel sections used for upright members, cross beams, or horizontal members shall be either tapered or constant cross section tubular members as specified herein. The tubular members may be either circular or multi-sided.

Box truss and bridge attached structures shall be fabricated from constant cross section tubular steel in accordance with to ASTM A 53, type E or S, grade B. Constant cross section tubular steel with greater yield strength may be used, with written approval. However, structural dimensions must remain as shown in the plans. Structures shall be galvanized after fabrication in accordance with ASTM A 123.

1240 Tri-cord truss, cantilever, and monotube structures shall be made of tapered tubular members in accordance with either ASTM A 595 or ASTM A 572M (ASTM A 572), grade 50, or of constant cross section tubular members in accordance with API High Test Line Pipe, grade X-52. Members shall have a minimum yield strength of 345 MPa (50,000 psi). Structures shall be galvanized after fabrication in accordance with ASTM A 123.

1250 Strain poles shall be anchor bolt type complete with hand-holes and pole top or cap. They shall meet the requirements set out above for cantilever sign structures. Each pole is to include 3 band type attachments for span wire clamps. The band shall be from material in accordance with ASTM A 572M (ASTM A 572), grade 50; ASTM A 606; or approved equal. The bands shall not be of the U-bolt type. The poles shall have maximum deflections as shown below when loaded 450 mm (18 in.) from the top with a 445 N (100 lb) load:

	Pole Size	Deflection
	380 mm x 910 mm (15 in. x 30 in.)	4.1 mm (0.16 in.)
1260	356 mm x 790 mm (14 in. x 26 in.)	3.0 mm (0.12 in.)

The steel flanges at the center of the cross beam and at the ends of the horizontal arms shall be fastened to the tapered or straight sections by means of two circumferential welds. One of the circumferential welds shall weld the outside of the flange firmly to the tube. The flange connection shall develop fully the strength of the tubular sections being joined together by means of the flange connections.

1270 Gusset, flange, and base plates shall be in accordance with ASTM A 36M (ASTM A 36) and shall be galvanized after fabrication in accordance with ASTM A 123. Base plates for upright poles shall develop the full strength of the poles. Castings for the vertical pole top and horizontal arm and cap shall be in accordance with ASTM A 126 and shall be galvanized with a minimum coating of 610.0 g/m² (2 oz/sq ft). Bolts, except anchor bolts, and nuts shall be in accordance with ASTM A 307. Two nuts for use in plumbing upright poles shall be furnished with each anchor bolt. Anchor bolts, except for box truss structures, shall be in accordance with ASTM A 675M (ASTM A 675), grade 90; ASTM A 576 modified to 379 MPa (55,000 psi) minimum yield strength; or ASTM A 307, grade A modified to 379 MPa (55,000 psi) minimum yield strength. Anchor bolts for box truss structures shall be in accordance with 910.19(a). Steel bolts, nuts, washers, and threaded ends of anchor bolts shall be 1280 coated in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153, class C. Welding shall be in accordance with 711.32.

1290 Beam clamp details and sign support assemblies shall be galvanized in accordance with ASTM A 153. Clamps shall be fabricated of high strength, low alloy steel in accordance with ASTM A 242M (ASTM A 242), ASTM A 606, or approved equal. Stainless steel U-bolts may be used in lieu of the clamps for the attachment of the sign hangers to the arms of double arm cantilevers. The U-bolts shall be in accordance with 910.19(a) for stainless steel hardware.

910.20 Steel Bridge Railing Components. Materials for steel bridge railing components shall be in accordance with the following.

- (a) Railing tubing shall be in accordance with ASTM A 500, Grade B.
- (b) Posts, connection plates, splice bars, base plates, and anchor channel bars shall be in accordance with ASTM A 36M (ASTM A 36).
- (c) Steel bolts, nuts, and cap screws shall be in accordance with ASTM A 307.
- 1300 (d) Railing end caps shall be steel castings in accordance with ASTM A 27M, grade 485-250 (ASTM A 27, grade 70-36).
- (e) Threaded rods, nuts, and washers shall be in accordance with AASHTO M 164.
- (f) Steel washers shall be standard round cut or lock washers, as shown on the plans.
- 1310 (g) Cap screws shall be stainless steel in accordance with ASTM A 276, type 304, 305, or 430.

- (h) Anchor bolts shall be stainless steel in accordance with ASTM A 276, type 305 or 430. However, they shall have a minimum ultimate strength of 690 MPa (100 ksi). Threads may be cut or rolled.
- (i) Railing tubing, posts, connection plates, splice bars, base plates, anchor channel bars, and railing end caps shall be galvanized after fabrication in accordance with AASHTO M 111.

1320

Bolts, nuts, cap screws, washers, and lock washers shall be galvanized after fabrication in accordance with AASHTO M 232.

- (j) Anchor bolts furnished under this specification shall be covered by a type A certification in accordance with 916. All other components furnished under this specification shall be covered by a type C certification in accordance with 916.

1330 **910.21 Steel Sheet Piling.** Steel sheet piling shall be in accordance with ASTM A 328M (ASTM A 328), ASTM A 569M (ASTM A 569), or ASTM A 525M (ASTM A 525).

SECTION 911 – WOOD MATERIALS

911.01 Untreated Lumber.

(a) General. Untreated lumber is a saw mill product which is not further manufactured than by sawing, resawing, passing lengthwise through a standard planing machine, cross cutting to length, and machining but is not treated with preservatives.

10 All lumber to be used without preservative treatment shall have the heart center completely boxed in pieces 150 mm (6 in.) and over in thickness. Pieces not large enough to box the center shall be cut outside the heart. Stringers, floor beams, and flooring shall have no less than 80% of heart on any girth. Caps, sills, and posts shall have no less than 60% of heart on each of the four sides measured across the side. Bracing, struts, rails, and such shall have no less than 80% on both sides measured across the side. If plans or purchase order are marked "Square Edge" no wane will be permitted.

20 **1. Boards.** Yard lumber less than 50 mm (2 in.) thick and more than 25 mm (1 in.) wide is a board.

2. Dimension Lumber. Lumber from 50 mm (2 in.) to but not including 125 mm (5 in.) thick and 50 mm (2 in.) or more wide is dimension lumber.

3. Structural Lumber. Lumber that is 50 mm (2 in.) or more thick and 100 mm (4 in.) or more wide intended for use where working stresses are required is structural lumber. The grading of structural lumber is based on the strength and use of the entire piece. Joists and planks shall be structural lumber. Dimensions and grade of lumber shall be as shown on the plans or as otherwise specified.

30 **4. Timbers.** Lumber of 125 mm (5 in.) or more in the least dimension is timber. Timbers may be classified as beams, stringers, posts, caps, sills, girders, purlins, etc. Timber for structural purposes shall be no less than 150 mm (6 in.) in width or thickness. Dimensions and grade of lumber shall be as shown on the plans or as otherwise specified.

40 **5. Timbers, Round.** These timbers are used in the original round form, such as poles, posts, and mine timbers. Round timbers, such as posts and poles, shall be entirely peeled. All limbs and knots shall be trimmed flush. Unless otherwise permitted or shown on the plans, no minus tolerances will be permitted on the specified diameter.

6. Yard Lumber. Lumber of all sizes and patterns that is intended for general building purposes is yard lumber. The grading of yard lumber is based on the intended use of the particular grade and is applied to each piece with reference to its size and length when graded without consideration to further manufacture.

7. Surfaced or Dressed Lumber. This is lumber that is dressed by running it through a planer.

50 **8. Rough Lumber.** Lumber as it comes from the saw is rough lumber.

(b) Species and Grade. Only coast region douglas fir, red oak group, redwood, long or short leaf southern yellow pine, and white oak group will be permitted, except as set out elsewhere herein. Redwood lumber shall not be used in bridges where it is a permanent part of the structure.

Except as otherwise provided, all lumber furnished under these specifications shall be of the species and grades specified.

60 Softwood lumber shall be graded in accordance with grade rules which conform with the basic provisions of the American Softwood Lumber Standard PS20-70. It shall be grade marked and shall be in accordance with the applicable grading rules or specifications of the following agencies for the species indicated:

Coastal Region Douglas Fir-West Coast Lumber Inspection Bureau

Southern Yellow Pine-Southern Pine Inspection Bureau

Redwood-Redwood Inspection Service

70

Red and White Oak Group, Hardwood Lumber, shall be grade marked and shall be in accordance with the applicable grading rules of the National Hardwood Lumber Association.

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If lumber is not to be graded as provided above, it may be green or seasoned, but shall be sound, free from excessive wane, unsound loose or hollow knots, knot holes, shakes, or other defects which would impair strength or durability for the use intended. Pin holes, shot holes, or occasional grub holes in oak are not classified as defects. If approved and if the proposed use of the material is stated on the purchase order, grade markings may not be required on native red or white oak groups furnished from local sources or on emergency orders or small orders of douglas fir and southern yellow pine.

Lumber for temporary bridges or other temporary structures may be of any species and grade which meets approval.

90

(c) Inspection. All lumber regardless of grade markings may be inspected for grades and quality at the point of origin or final destination. If, during inspection of a lot of lumber, it becomes apparent that the quantity of rejections exceed 20%, the entire lot may be rejected.

(d) Tolerances. Tolerances for rough sawed, or dressed lumber shall be in accordance with the following table.

Nominal Dimensions		Rough Lumber Tolerances*		Surfaced Lumber Tolerances (SIS and S2S to S4S)	
Thickness mm (in.)	Width mm (in.)	Thickness mm (in.)	Width mm (in.)	Thickness mm (in.)	Width mm (in.)
25 (1)	under 203 (8)	3 (1/8)	6 (1/4)	6 (1/4)	10 (3/8)
	203 (8) and over	3 (1/8)	10 (3/8)	6 (1/4)	13 (1/2)
50 (2)	under 200 (8)	6 (1/4)	6 (1/4)	10 (3/8)	10 (3/8)
	203 and over (8)	6 (1/4)	10 (3/8)	10 (3/8)	13 (1/2)
Over 50 (2) but Less than 203 (8)	under 203 (8)	6 (1/4)	6 (1/4)	10 (3/8)	10 (3/8)
	203 and over (8)	6 (1/4)	10 (3/8)	10 (3/8)	13 (1/2)
203 (8) and over	203 (8)and over	10 (3/8)	10 (3/8)	13 (1/2)	13 (1/2)

* If full size rough lumber is specified, no minus tolerances will be permitted.

(e) Untreated Piling. Untreated piles shall be cut from white or red oak, dense southern yellow pine, fir, or cypress, preference given in the order named. Subject to approval, they may be of other species which can withstand driving without showing excessive brooming or splitting.

All piling shall have been cut from sound, solid, live trees. They shall contain no ring shakes, dote, or unsound knots. Sound knots will be permitted provided the diameter of the knot does not exceed 100 mm (4 in.) or 1/3 of the diameter of the pile where it occurs, whichever is the smaller. Any defects, or combination of defects, which impair the strength of the pile will not be permitted. The piles shall be free from twist of grain exceeding 1/2 of the circumference in any 6.1 m (20 ft) of length. The butts shall be sawed square and the tips sawed square or tapered to a point of not less than 10 300 mm² (16 in.) with the tip so formed that the centerline of the pile passes through the tip.

Unless otherwise specified, all piles shall be peeled before driving by removing all the rough bark and at least 80% of the inner bark. No strip of the inner bark remaining on the pile shall be more than 19 mm (3/4 in.) wide and there shall be at least 25 mm (1 in.) of barkfree surface between any two such strips. Not less than 80% of the surface on any one circumference shall be clean wood. Piles shall be cut above the ground swell, and shall have a uniform taper from butt to tip. All knots shall be trimmed flush with the body of the pile.

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 1% of the length of the pile. In short bends, the distance from the center of the pile to a line stretched from the center of the pile above the bend to the center of the pile below the bend shall not exceed 4% of the length of the bend, but in no case more than 63 mm (2 1/2 in.). Piles shall be free from reverse bends.

After peeling, piles shall have diameters as indicated below unless otherwise approved or required.

Length of Pile	Diameter - Inches (mm)		
	Tip Minimum	3' from Butt Minimum (0.9 m)	Butt Maximum
Less than 6.1 mm (20 ft)	203 (8)	279 (11)	508 (20)
6.1 m (20 ft) and less than 12.2 m (40 ft)	203 (2)	305 (12)	508 (20)
12.2 m (40 ft) and less than 18.3 m (60 ft)	178 (7)	330 (13)	508 (20)
18.3 m (60 ft) and more	152 (6)	330 (13)	508 (20)

911.02 Treated Lumber.

(a) General. Treated lumber shall be lumber which is preservative treated by pressure processes in accordance with the AWPAs Standards. AWPAs Standard C1 specifies general requirements for all wood products. Other AWPAs Standards applying to specific items are set out in 911.02(b), 911.02(c), 911.02(d), and 911.02(e). Lumber to be treated shall be in accordance with 911.01, except as modified in 911.02(b) 911.02(c), 911.02(d), and 911.02(e). The lumber may be inspected at the treating plant. Preservatives shall be in accordance with 911.02(f).

140

(b) Bridge Lumber. This shall be southern yellow pine or coast region douglas fir, there shall be no heartwood requirements and the amount of sapwood shall not be limited. Wane will not be permitted on any treated plank for flooring and may be excluded elsewhere when so specified. In other lumber, wane shall not exceed 1/8 of the width of any face and 1/4 of the length of the piece on any one corner. Both the outer and inner bark shall be removed from any area where wane is permitted. Lumber for bridges shall be treated with a preservative in accordance with applicable provisions of Standard C14 and C2 of the AWPAs Standards.

150

(c) Piling. Wood piling, before treatment, shall be in accordance with 911.01(e) except piles shall be southern yellow pine, red oak, or coast region douglas fir. The outer and inner bark shall be removed before treatment. Unless otherwise specified, piling shall be treated with creosote in accordance with the applicable provisions of Standards C14 and C3 of the AWPAs Standards.

160

(d) Guardrail Posts, Braces, and Battens. Wood for these items shall be cut from live, dense southern yellow pine, coast region douglas fir, red oak, or other species if so designated in the proposal or purchase order. Posts shall be rough sawed unless otherwise specified. Dimensions shall be as shown on the plans. There shall be a length tolerance of plus 50 mm (2 in.) for posts. The bottoms shall be sawed square and the tops roofed as shown on the plans. Wane shall not extend more than 0.6 m (2 ft) from the bottom end. Knots shall be closely trimmed, but hollow knots extending in close to the center of the post, loose knots, and knot clusters will not be permitted. Posts shall be practically straight and no post with a crook exceeding 25 mm (1 in.) between top and butt will be accepted.

170

Posts listed above shall be sound posts. No sapwood rot will be permitted. Ring shake will not be permitted and oak posts shall be free from pecks or excessive grub holes. Grub holes in the butt, 13 mm (1/2 in.) or less in diameter, are not considered defects. Posts containing ant holes will not be accepted. Any post which contains any defect which is detrimental to the post will be rejected.

Wood braces and battens shall be of the same general species and specifications as required for the posts and shall be of the dimensions shown on the plans.

Wood guardrail posts, and wood parts in connection with guardrails, shall be treated with a preservative in accordance with the applicable provisions of Standards C14 and C2 of the AWPAs Standards.

180 **(e) Sign Posts.** Wood sign posts shall be cut from live catalpa; northern white cedar; native red cedar; southern red cedar; black locust; yellow locust; mulberry; red, black, and white oak group; osage orange; dense southern yellow pine; redwood; sassafras; coast region douglas fir, or other species as specified. Posts shall be surfaced four sides.

Dimensions shall be in accordance with the plans. There shall be a length tolerance of 50 mm (2 in.). Both butt and top ends shall be sawed square. All outer and inner bark shall be removed. One way sweep, not exceeding 25 mm (1 in.) between the top and the butt, will be acceptable. Short crooks will not be permitted.

190 The posts shall be sound timber. No splits, shakes, excessive cracks, loose decayed or hollow knots will be permitted. Occasional pin, shot, or grub holes in oak, or bird pecks in other timbers, will not be considered defects. All posts shall be entirely treated with preservatives in accordance with all applicable provisions of Standards C14 and C2 of the AWPAs Standards. The oil carrier shall be a heavy petroleum solvent in accordance with the applicable provisions of Standard P9 of the AWPAs Standards and shall be of such characteristics that the posts will be suitable for painting with an oil base paint.

200 **(f) Sawed Timber Posts and Blocks for Thrie-Beam and W-Beam Guardrail.**
The requirements for posts and blocks prior to treatment shall be as shown below.

1. Species and Grades. Wood posts shall be of the species listed, and shall be in accordance with the grading requirements specified in Table A. Wood blocks shall be of the species listed, and shall be in accordance with the grading requirements specified in Table B. Wood posts and blocks shall have a nominal cross section and dimensions as shown on the plans.

TABLE A

SPECIAL AND GRADING REQUIREMENTS FOR SAWED TIMBER GUARDRAIL POSTS		
SPECIES	POSTS & TIMBERS GRADE	GRADING RULES AGENCIES ^a
HARDWOODS		
Red Oak (Northern Red, Black, Pin, Laurel, Cherry-Bark, Scarlet, Water and Willow Oaks) ^b , Hard Maple (Black & Sugar) and Red Maple White Ash White-Heartwood Beech Yellow Birch Hickory (Mockernut, Pignut, Shagbark, and Shellbark Hickories)	Grade GRP	Department
SOFTWOODS		
Douglas Fir, Douglas Fir-Larch Southern Pine Jack Pine 200 mm x 200 mm (8 in. x 8 in.)	No. 1 or better No. 1 or better No. 1 or better	WWPA or WCLIB SPIB NHPMA

^a NHPMA (Northern Hardwood and Pine Manufacturers Assoc.); WWPA (Western Wood Products Assoc.); WCLIB (West Coast Lumber Inspection Bureau); and SPIB (Southern Pine Inspection Bureau).

^b Southern Red Oak will not be permitted.

Posts and blocks shall be graded in accordance with grading rules based on principles and methods specified in ASTM D 245. Where there is a conflict between AWPMA and ASTM standards, AWPMA will prevail. Where there is a conflict between either AWPMA or ASTM standards and this specification, this specification will prevail.

All material shall show the approved grading agency stamp indicating mill origin, species, and grade.

TABLE B

SPECIES AND GRADING REQUIREMENTS FOR SAWED TIMBER GUARDRAIL BLOCKS		
SPECIES	POSTS & TIMBERS GRADE	GRADING RULES AGENCIES
HARDWOODS		
Red Oak (Northern Red, Black Pin, Laurel, Cherry-Bark, Scarlet, Water and Willow Oaks) ^b , Hard Maple (Black & Sugar) and Red Maple, White Ash, White-Heartwood, Beech, Yellow Birch Hickory (Mockernut, Pignut, Shagbark, and Shellbark Hickories)	Grade GRP	Department
SOFTWOODS		
Douglas Fir, Douglas Fir-Larch Southern Pine Species Jack Pine, Red Pine, and Eastern White Pine (Northern White Pine)	No. 2 or better No. 2 or better No. 1 or better.	WWPA or WCLIB SPIB NHPMA

^a NHPMA (Northern Hardwood and Pine Manufacturers Assoc.); WWPA (Western Wood Products Assoc.); WCLIB (West Coast Lumber Inspection Bureau); and SPIB (Southern Pine Inspection Bureau)

^b Southern red oak will not be permitted

2. Department Grade GRP. The requirements for posts to be in accordance with the Department's Grade GRP, Guardrail Posts, will be as follows:

230 **a. Splits.** Splits in the plane of the bolt hole shall not exceed 75 mm (3 in.). At other locations, splits shall not exceed 150 mm (6 in.).

b. Checks. Single checks shall not be greater than 75 mm (3 in.) deep. Checks opposite each other shall not total more than 75 mm (3 in.) deep, as measured with a probe that is not more than 1.6 mm (1/16 in.) in thickness or in diameter.

240 Single checks of 6 mm (1/4 in.) wide, or wider, measured at the widest point, shall not extend more than one third of the length of the post. Single checks, measured at the widest point, shall not exceed 10 mm (3/8 in.) in width.

c. Shakes. Shakes, measured in the least dimension, shall not exceed 50 mm (2 in.).

 Splits, checks, and shakes shall not be in combinations which may cause the post to separate into several pieces.

d. Stains. Stained heartwood, not caused by decay, shall not exceed 25% of the piece.

250 **e. Slope of Grain.** Slope of grain shall not exceed 1 in 10.

f. Wane. Wane shall be less than one quarter of each face.

g. Knots. Knots shall be sound and tight. The sum of the least dimensions of all knots in a 150 mm (6 in.) length of post, all faces, shall be less than 125 mm (5 in.). Grain distortion caused by knot clusters shall not exceed 63 mm (2 1/2 in.). Knots will be permitted on all faces, but knots shall not exceed 63 mm (2 1/2 in.) in the least dimension.

260 **3. Department Grade GRB.** The requirements for blocks to be in accordance with the Department's Grade GRB, Guardrail Blocks, will be as follows:

a. Splits. Splits in the plane of the bolt hole shall not exceed 75 mm (3 in.). At other locations, splits shall not exceed 125 mm (5 in.).

b. Checks. Checks shall be in accordance with 910.02(f)2b.

270 **c. Shakes.** Shakes, measured in the least dimension, shall not exceed 75 mm (3 in.). Shakes shall not extend beyond half the standard grading length of the piece.

Splits, checks, and shakes shall not be in combinations which may cause the block to separate into several pieces.

d. Stains. Stained heartwood, not caused by decay, shall not exceed 25% of the piece.

e. Wane. Wane shall be less than one third of each face.

280 **f. Knots.** Grain distortion caused by knot clusters shall not exceed 100 mm (4 in.). Knots will be permitted on all faces, but knots shall not exceed 100 mm (4 in.) in the least dimension.

4. General Requirements. Posts and blocks shall be in accordance the following general requirements.

a. Decay. Posts and blocks shall be free from decay before treatment.

290 **b. Unsound Wood.** Posts containing unsound wood will be rejected. Blocks may contain small spots of unsound wood provided they are well scattered.

c. Crook or Bow. Crook or bow shall not exceed 25 mm per 3 m (1 in. per 10 ft) length.

d. Dimensional Tolerances. Posts and blocks shall be sawed square to within -13 mm (-1/2 in.) of the specified cross-sectional dimensions. A tolerance of -5.8 mm (-2 in.) will be permitted on the specific length of the posts. A tolerance of -13 mm (-1/2 in.) will be permitted on the specified length of the blocks.

300 **5. Pressure Treating Posts and Blocks.** Pressure treating posts and blocks shall be in accordance with the following requirements.

a. Machining. Posts and blocks shall be sawed to their final shape and holes bored prior to treatment.

b. Blank.

310 **c. Inspection Before Treatment.** The treater shall be responsible for ensuring that the material has the required approved grading agency stamp before treatment is commenced. The stamp or marking shall be applied on a wide face at the trimmed end. The stamp shall be applied such that it remains readable after treating. Material that has been air dried or kiln dried shall be inspected for moisture content as specified below, in accordance with AWPAs Standard M2. Tests of representative pieces shall be conducted. The minimum number of tests shall be the lesser of 5% or 50 pieces out of a charge.

d. Test for Moisture Content. The test shall be made with an electrical resistance type moisture meter with insulated needles of 38 mm (1.5 in.) in length. The readings shall be corrected for species and temperature readings in accordance with the meter instructions. The readings shall be taken on one surface at mid-length with needles driven to their full length. The lot will be considered acceptable when the average moisture content does not exceed 19%. Individual pieces exceeding 23% moisture content will be rejected. Such pieces shall be removed from the lot.

e. Preservative Treatment. All posts and blocks shall be treated with a preservative as specified herein.

f. Material for Preservative Treatments. The preservative used for treating posts and blocks shall be in accordance with the appropriate AWP standards listed in Table C.

TABLE C

MATERIAL	AWPA Standard
Ammoniacal Copper Arsenate (ACA)	P5
Ammoniacal Copper Arsenate (ACZA)	P5
Chromated Copper Arsenate (CCA)	P5

g. Treatment Methods. Wood for guardrail posts and blocks shall be treated to be in accordance with AWP Standards C1 and C2, ASTM D 1760, and the requirements specified herein.

h. Sorting and Spacing. The material in a charge shall consist of the same species or consist of species within one group shown in Table D. The material shall have similar moisture content and be of similar form and size. Blocks and posts may be treated in the same charge.

Pieces in the charge shall be separated by horizontal stickers so that preservative and steam, if used, shall contact all horizontal surfaces.

TABLE D

SPECIES GROUPINGS FOR TREATMENT IN SAME CHARGE	
GROUP	SPECIES
A	Southern Pine
B	Douglas Fir
C	Jack Pine*
D	Hardwoods

* Also Red Pine and Eastern White Pine Blocks

350

i. Conditioning. Material may be conditioned by means air seasoning, kiln drying, Boulton drying, vapor drying, steaming, or heating in preservative except as limited herein. Material which is air seasoned or kiln dried shall have an average moisture content not exceeding 19% before treatment. When steam conditioning, the maximum temperature shown in Table E shall not be reached in less than 1 h. If a vacuum is applied after steaming, it shall be a minimum of 560 mm (22 in.) of mercury. In addition, when using CCA, ACA, or ACZA, material shall be removed from the cylinder and permitted to cool to 49EC (120EF), or below, after steaming and before the preservative is applied. When treating southern pine, jack pine, and red pine with CCA, ACA, or ACZA, steaming will only be permitted to thaw frozen or ice coated material.

360

When conditioning by heating in preservative, the solution shall cover the material. Maximum temperatures permitted shall be those shown in Table E. Conditioning by means of heating in water-borne preservatives CCA, ACA, or ACZA will not be permitted.

TABLE E

CONDITIONING METHODS PERMITTED AND TEMPERATURE REQUIREMENTS FOR METHOD USED					
		HEATING IN			
		STEAMING		PRESERVATIVE	
SPECIES	CONDITIONING METHODS PERMITTED	Max.Temp EC (EF)	Max. Duration Hrs	Max.Temp EC (EF)	Max. Duration Hrs
Hard Maple	Air drying only				
Other Hardwoods ⁽¹⁾	No Steaming			104 (220)	No Limit
Southern Pine	Shown in 901.02(f)5I	118 (245)	17	104 (220)	No Limit
Eastern White Pine	All	116 (240)	4 1/2	99 (210)	6 (3)
Other Softwoods ⁽²⁾	Shown in 910.02(f)5I	116 (240)	6	99 (210)	6 (3)

j. Blank.

370

TABLE F

MAXIMUM TEMPERATURE OF THE PRESERVATIVE DURING THE ENTIRE PRESSURE PERIOD	
Material	Max. Temp. EC (EF)
Ammoniacal Copper Arsenate (ACA)	66 (150)
Chromated Copper Arsenate (CCA)	49 (120)
Ammoniacal Copper Zinc Arsenate (ACZA)	66 (150)

k. Inspection During Treatment. The treater shall determine that the preservatives used are in accordance with the requirements herein. The minimum frequency of the preservation analyses shall be each charge for the occasional single charge inspected. The minimum frequency for consecutive treatments from the same working tank shall be the first and at least one of every five additional charges, selected at random. Preservative samples shall be taken as appropriate so as to be representative of the solution in the treating cylinder.

l. Retentions. The minimum retentions in kg/m³ (lb/cu ft) for the outer 15 mm (0.6 in.) of guardrail posts and blocks shall be those listed in Table G. Retentions shall be determined by chemical assay with samples taken after treatment in accordance with the inspection after treatment requirements shown below and the AWP Standards listed in Table G.

TABLE G

MINIMUM REQUIREMENTS FOR RETENTION OF PRESERVATIVE			
PRESERVATIVE	RETENTION kg/m ³ (lb/cu ft)		AWPA STANDARD
	POSTS	BLOCKS	
CCA, ACA, OR ACZA	9.61 (0.60)	6.41 (0.40)	A11

If blocks are treated along with posts, retention of the charge shall be determined by assay of borings from posts.

m. Penetration. The penetration requirements for heartwood and sapwood shall be as specified in Table H. Samples to determine penetration shall be taken after treatment in accordance with the inspection after treatment requirements shown below.

TABLE H

PENETRATION REQUIREMENTS FOR POSTS AND BLOCKS		
SPECIES	MINIMUM PENETRATION	
	HEARTWOOD	SAPWOOD
Permitted Species*	8 mm (0.3 in.)	15 mm (0.6 in.) or 90%, whichever is greater

* For Red Oak, 65% of the total annual rings shall be penetrated. If this is not possible, properly conditioned wood may be treated to refusal.

n. Inspection After Treatment. Following treatment, the charge shall be examined by the treater for cleanliness; mechanical damage to individual pieces; treatment damage such as severe checking, splitting, or honeycombing; and for untreated areas resulting from air pockets, floating material, or insufficient height of preservative. All such material shall be removed from the remaining acceptable material before shipment.

Sampling and testing for preservative retention and penetration will be done by the Department.

o. Branding. All posts and blocks shall be burn branded clearly and permanently on one of the wide faces. The brand shall be within 300 mm (12 in.) of the top of the post. The brand shall show the treater's identification, the plant designation, and the year of treatment. The month may also be included. The brand shall also show the species or group code designation shown in Table I, the preservative type, and retention, all in accordance with AWPAs Standard M6.

p. Conformance. The treating plant supplying the material shall be responsible for and will be required to supply a certificate indicating the species, grade, preservative type, retention, year, and name of treater.

TABLE I

GROUP CODING AS AN ALTERNATE TO SPECIES CODING*	
GROUP	CODE
Hardwoods	MH
Jack Pine	J
Other Softwoods	MS

* Species designated in Tables A and B

q. Records. Copies of treating records, analysis records, and other records which may be necessary to determine accordance with specifications shall be made available to Department personnel or their designated representatives upon their request. Required information shall be that which is listed in Part 7.2 of AWPAs Standard M2. These records shall be retained by the treating plant for five years from the date of material shipment.

r. Independent Inspections. The Department may inspect the material or call for a non-Departmental inspection to verify that it is in accordance with all specifications.

6. Field Treatment of Posts and Blocks. Cuts, holes, or injuries to the surface of posts and blocks which occur after pressure treatment shall be field-treated by brushing, spraying, dipping, soaking, or coating. The Contractor shall ensure that all injuries, such as abrasions and nail and spike holes, are thoroughly saturated with the field-treating solution. Holes bored in pressure-treated materials shall be poured full of preservative. Horizontal holes may be filled by pouring the preservative into the holes with a bent funnel after temporarily plugging the other end of the hole.

The solution used for field treatment shall be a 20% solution of copper naphthenate.

7. Rejection for Degradation After Treatment. Guardrail posts or blocks developing the following degradation prior to installation will be rejected regardless of prior approvals.

- 460
- a. single checks greater than 75 mm (3 in.) deep or checks opposite each other totaling more than 75 mm (3 in.) deep, measured with a probe not more than 2 mm (1/16 in.) thick;
 - b. single checks 6 mm (1/4 in.) wide or wider measured at the widest point, and extending more than one third of the length of the post or block;
 - c. single checks greater than 10 mm (3/8 in.) wide measured at the widest point;
 - d. splits greater than 75 mm (3 in.) long which are in the plane of the bolt hole;
 - e. crooks or bows exceeding 25 mm (1 in.) per 3.0 m (10 ft) length, and all twists;
 - f. combinations of checks, splits, or shakes which are otherwise in accordance with the specifications but which may cause the post or block to separate into several pieces.
- 470

(g) Preservatives. Preservatives shall be in accordance with AASHTO M 133 as modified by EPA regulation.

1. Waterborne Preservatives. Waterborne preservatives shall be in accordance with AWWA-P5, and shall be Acid Copper Chromate, Ammoniacal Copper Arsenate, or Chromated Copper Arsenate.

SECTION 912 – CONCRETE CURING MATERIALS AND ADMIXTURES

912.01 Curing Materials. Curing materials shall be in accordance with the following requirements.

10 **(a) Burlap Cloth made from Jute or Kenaf.** This material shall be new, or reclaimed and thoroughly vacuum cleaned burlap. Burlap from sugar, salt, or fertilizer bags shall not be used. The burlap shall weigh no less than 3.4 kg/² (10 oz/sq yd) and shall be in strips of not less than 1.0 m (40 in.) nor more than 3.0 m (120 in.) wide and no less than 0.60 m (2 ft) longer than the width of the pavement being cured.

(b) Waterproof Paper Blankets. These blankets shall be in accordance with AASHTO M 171.

(c) White Polyethylene Sheeting, Film. The sheeting shall be in accordance with AASHTO M 171.

(d) White Burlap Polyethylene Sheet. These sheets shall be in accordance with AASHTO M 171.

(e) Liquid Membrane Forming Compounds. These compounds shall be in accordance with AASHTO M 148, type 2, except the drying time requirement will be determined on a glass surface.

(f) Polyethylene Film. The sheeting shall be in accordance with AASHTO M 171.

912.02 Curing-Sealing Materials. Curing-sealing materials are single application curing and sealing products for portland cement concrete.

A List of Approved Curing-Sealing Materials will be maintained by the Department. The list will identify preapproved products, specify the manufacturer and product designation, and include application instructions.

In order to have a product added to the List of Approved Curing-Sealing Materials, the manufacturer shall furnish to the Materials and Tests Division a type A certification in accordance with 916. Such certification shall state that the product is in accordance with the requirements of NCHRP 244 Series IV Southern Climate Weathering Test, and AASHTO M 148 Type 1.

(a) The certification shall be in accordance with the applicable requirements of 916, and shall include a dated test report. The test report shall substantiate full compliance with the specifications and establish when the testing was started. Test reports older than seven years on January 1 of the approval year will not be accepted.

(b) If irregularities are found in the results required for such certification, copies of the original data may be required prior to reconsideration of the certification.

(c) Tests must be conducted by a state highway agency testing laboratory or a testing laboratory regularly inspected by CCRL. Proof of such inspection shall be furnished with the test report.

After a product has been approved, it will be added to the List of Approved and/or Prequalified Materials. The product will remain on the List until test results on file are seven years old, provided that there are no changes in raw materials, formulation, or procedures for manufacture. Results more than seven years old or products in which there has been a change in raw materials, formulation, or procedures for manufacture shall be recertified in order to remain on the List.

A curing-sealing material that performs unsatisfactorily in the field will be removed from the approved list.

912.03 Admixtures for Use in Concrete. Admixtures containing chloride added as an ingredient of manufacture are unacceptable.

(a) Air Entraining Admixtures. Air entraining admixtures are materials to be added to portland cement concrete mixtures at the mixer for the purpose of entraining air. These admixtures shall be in accordance with AASHTO M 154.

(b) Chemical Admixtures for Concrete. Chemical admixtures are materials to be added to portland cement concrete mixtures at the mixer for the purpose or purposes indicated below. The admixtures shall be in accordance with AASHTO M 194 for their respective types.

1. Type A. Type A is a water reducing admixture that reduces the quantity of mixing water required to produce concrete of a given consistency.

2. Type B. Type B is a retarding admixture that retards the setting of concrete.

3. Type C. Type C is a accelerating admixture that accelerates the setting and early strength development of concrete.

4. Type D. Type D is a water reducing and retarding admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and retards the setting of concrete.

5. Type E. Type E is a water reducing and accelerating admixture that reduces the quantity of mixing water required to produce concrete of a given consistency and accelerates the setting and early strength development of concrete.

6. Type F. Type F is a high range water reducing admixture, HRWR, that reduces the quantity of mixing water required to produce concrete of a given consistency by 12% or greater.

7. Type G. Type G is a high range water reducing and retarding admixture, HRWRR, that reduces the quantity of mixing water required to produce concrete of a given consistency by 12% or greater and retards the setting of concrete.

8. High Range Water Reducing and High Range Water Reducing and Retarding Admixture Systems. HRWR and HRWRR admixture systems typically utilize an air entraining agent; a type A or type D chemical admixture; and a type F chemical admixture, for HRWR, or a type G chemical admixture, for HRWRR.

(c) Certification. Prior to furnishing admixtures, each manufacturer shall furnish to Division of Materials and Tests a certification in accordance with the following:

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1. For air entraining admixtures manufactured by neutralizing Vinsol resin with sodium hydroxide in accordance with AASHTO T 157, the certification shall certify that:

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- a. the product is (brand name);
- b. is manufactured by (manufacturer's name);
- c. is an aqueous solution of Vinsol resin that has been neutralized with sodium hydroxide;
- d. the ratio of sodium hydroxide to Vinsol resin is one part of sodium hydroxide to (number) parts of Vinsol resin by mass (weight);
- e. the percentage of solids based on residue at 105EC (221EF) is (number);
- f. no other additive or chemical agent is present in this solution.

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If the air entraining admixture is manufactured in proportions other than set out in AASHTO T 157 for the referenced admixture, the certification shall include a dated test report substantiating compliance with the specifications.

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2. For type A, B, C, D, E, F, and G admixtures, the certification shall:
 - a. state the chloride content;
 - b. state whether or not chloride is added as an ingredient of manufacture;
 - c. state that the admixture complies with these specifications;
 - d. include a dated test report substantiating full compliance with the specifications. If irregularities are found in the test results required for the aforementioned certification, copies of the original data may be required to be submitted prior to reconsideration of the certification.

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3. For HRWR and HRWRR admixture systems that contain an air entraining agent; a type A or type D chemical admixture; and a type F or type G chemical admixture, the certification shall:

- a. state the product names;
- b. state the manufacturer's name(s);
- c. state the character of the materials;
- d. state the chloride contents;
- e. state whether or not chloride is added as an ingredient of manufacture;
- f. state that the type A or type D chemical admixture and the air entraining agent is in accordance with 912.03(c) for their respective types;
- g. include a dated test report substantiating full compliance of the type F or type G chemical admixture with 912.03(c) and AASHTO M 194;
- h. include a dated test report substantiating full compliance of the HRWR or HRWRR admixture system with AASHTO M 194 for type F or type G chemical admixture, except as follows:
 - (1) The HRWR or HRWRR admixture system shall be used in the test concrete.
 - (2) The control concrete shall contain the same air entraining agent used in the HRWR or HRWRR admixture system.
 - (3) The six month and one year compressive strength testing will be waived and flexural strength testing will not be required.
 - (4) Uniformity and equivalence testing will not be required.
 - (5) Testing for length change shall not be required.

- (6) A sample of the test concrete containing the HRWR or HRWRR admixture system shall be tested for hardened concrete air void system analysis in accordance with ASTM C 457. The sample for hardened concrete air void system analysis shall indicate an air content of at least 4.5% for class C, and 5.2% for class A; a voids per millimeter (inch) parameter of at least 0.0492 (1.25) times the air content; a spacing factor of 0.254 mm (0.010 in.) or less; and a specific surface of 19.685 mm²/mm³ (500 in.²/in.³).

4. The tests shall be performed by a recognized laboratory which is a state highway agency testing laboratory, or a cement or concrete laboratory regularly inspected by the CCRL. Proof of such inspection shall be furnished on request. The test report shall be dated to establish when the testing was started. Test reports shall not be more than five years old on January 1 of the approval year. New submittals of AASHTO M 194 test reports more than five years old will be accepted, if all subsequent five year limited retest reports, are submitted. Subsequent limited retest results shall comply with the dating and age requirements specified above and shall include the following AASHTO M 194 tests as a minimum requirement for compliance.

- a. infrared analysis, residue by oven drying, and specific gravity;
- b. water content and time of setting as referenced in AASHTO M 194;
- c. flexural strength at three, seven, and 28 days;
- d. relative durability.

After the certification specified in the preceding paragraph has been approved and provided that the required test results are still not more than five years old as specified above, each manufacturer shall submit an annual certification of compliance with those specifications as previously described except, if there has been no change in raw materials, formulation, or procedures, test results will not be required. The certification shall indicate that the material is of the same formulation as that for which test results have been submitted. When the initially submitted test results are more than five years old as specified above, a complete certification with new limited retest results shall be required.

(d) Approved Admixtures. The Department will maintain a list of Approved Admixtures and Approved Admixture Systems.

(e) Performance of Admixtures. The use of concrete admixtures which results in unsatisfactory performance will be prohibited.

240 **912.04 Latex Modifiers.** The latex modifiers are an admixture to be added to the concrete mixture at the continuous mixer. The latex shall be one of the latex modifiers in the list of approved Admixtures for Portland Cement Concrete.

The formulated latex admixture shall be a non-toxic, film forming, polymeric emulsion in water to which all stabilizers have been added at the point of manufacture and shall be homogeneous and uniform in composition. A type B certification shall be furnished in accordance with 916.

Physical properties of the latex modifier shall be in accordance with the following:

250

Polymer Type.....	Styrene Butadiene
Stabilizers.....	Anionic and Nonionic Surfactants
Antifoaming Agent	Polydimethyl Siloxane
Percent Solids, % by mass.....	46.0 Minimum
Mass Per Liter (Gallon)	1.0 kg (8.4 lb) at Minimum
pH (as shipped).....	9.0-11.0
FreezeThaw Stability	Five Cycles, -15E to 25EC
Shelf Life	Two Years, Minimum
Color.....	White

260

SECTION 913 – MISCELLANEOUS

913.01 Water. Water used in mixing or curing shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substance injurious to the finished product. Water will be tested in accordance with AASHTO T 26. Water shall be in accordance with the requirements as follows:

- 10
- (a) pH..... 6 to 8.
 - (b) Chloride Ionsless than 300 ppm.
 - (c) Sulphate (SO₄).....less than 500 ppm.
 - (d) Total Solids.....less than 1500 ppm.

In addition, water containing algae will be unacceptable for use in concrete. Water known to be of potable quality may be used without test. Where the source of water is relatively shallow, the intake shall be so enclosed as to exclude silt, mud, grass, or other foreign materials.

913.02 Calcium Chloride. Calcium chloride shall be in accordance with AASHTO M 144 and shall be:

- (a) Type S, grade 1, class A
- (b) Type S, grade 3, class A or B
- (c) Type L

913.03 Sodium Chloride. Sodium chloride shall be in accordance with AASHTO M 143. Rock salt shall be used for de-icing purposes. Either rock salt or evaporated salt may be used for stabilization.

913.04 Lime. Lime shall be a hydrated lime when used in masonry or a hydrated lime, quicklime or lime by-product when used for soil modification.

(a) Hydrated Lime for Masonry. Hydrated lime used in masonry shall be in accordance with ASTM C 207, Type N.

(b) Lime for Soil Modification.

1. Hydrated Lime and Quicklime. Hydrated lime and quicklime shall be in accordance with AASHTO M 216.

2. Lime By-Products. Lime by-products shall be hydrated lime or quicklime by-products in accordance with ASTM C 25 having the following requirements:

- a. The lime by-products shall contain a minimum of 60% total available calcium and magnesium oxides (non-volatile basis).
- b. Available calcium hydroxide plus magnesium oxide calculated as calcium hydroxide shall be a minimum of 30%.
- c. Sieve analysis shall be performed in accordance with ASTM C 110. The lime by-products gradation shall be as follows:

Sieve	% Passing
4.75 mm (No. 4)	95-100
600 µm (No. 30)	90-95
150 µm (No. 100)	70-80

913.05 Precast Concrete Curbing. Precast concrete curbing shall consist of precast portland cement concrete curb units constructed to the length, shapes, and other details shown on the plans. These units shall be reinforced with steel reinforcement when shown on the plans. Steel reinforcement shall be in accordance with 910.01.

When required for driveways, crossings, closures, or for other reasons a depressed or modified section of curb is indicated, curbing with the required modification shall be furnished.

70 **913.06 Precast Concrete Units Not Otherwise Covered.** These units shall be cast in substantial permanent steel forms. Structural concrete used shall attain a minimum 28 day compressive strength of 20.7 MPa (3,000 psi) as determined in accordance with AASHTO T 22. When air entrained concrete is specified, it shall have an air content of from 5% to 8% by volume. The precast units shall be cured in accordance with AASHTO M 170. Water absorption of individual cores taken from such units shall not exceed 9%. Additional reinforcement shall be provided as needed to handle the precast units.

80 **913.07 Flexible Delineator Posts.** Flexible delineator posts shall be made of flexible plastic material. The post shall be straight and have a smooth surface free from cracks, flaws, seams, laps, blisters, and edges affecting the strength, durability, or appearance. The cross section of the post may be round, oval, or T shaped and the width shall not exceed 150 mm (6 in.). They shall be white, yellow, or orange in color as determined by the location in which they are used.

The reflective device on these posts shall be reflective sheeting matching the color of the posts, in accordance with 912.10(d)4, and shall have minimum dimensions of 75 mm (3 in.) by 200 mm (8 in.). The reflective device shall be applied directly to the post and protected in a manner that minimizes the damage upon impact.

90 When installed the flexible post shall withstand, without damage, repeated impacts from a motor vehicle's front bumper at speeds up to 80 km/hr (50 mph) at ambient air temperatures from -7EC (20EF) to 49EC (+120EF). It shall be able to bend to an angle of 85 degrees from vertical and right itself to within 10 degrees of the vertical immediately and stand erect within 4 h within the same ambient air temperature range.

100 Manufacturers of flexible delineator posts shall prequalify for supply by providing the Operations Support Division with posts for field evaluation to determine acceptability. The Department will maintain a list of approved flexible delineator posts.

913.07.1 Flexible Channelizer and Flexible Tubular Marker. The vertically placed portion of each device shall consist of high density polyethylene plastic in accordance with ASTM D 5203. The base material shall be butyl rubber in accordance with ASTM D 5900. Epoxy material used to attach the base to the roadway surface shall be in accordance with the manufacturer's recommendations. The tubular portion of the flexible tubular marker shall be covered with high intensity reflective sheeting in accordance with 913.10(d).

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913.08 Delineators.

(a) Acrylic Plastic Delineators. These units shall consist of a hermetically sealed optical system with a circular plastic face and prismatic molded rear surface. The optical system shall have a minimum diameter of 75 mm (3 in.) with a minimum area of approximately 4520 mm² (7 in.²). The trademark of the manufacturer shall be molded legibly into the face of the lens. Color shall be clear (crystal or silver) or yellow in daylight as well as when viewed by reflected light at night. Photometric or optical requirements shall equal or exceed the following minimum values:

Observation Angle Degrees	Entrance Angle Degrees	Specific Intensity lux (footcandles)	
		Clear	Yellow
0.1	0	1281 (119)	850 (79)
0.1	20	506 (47)	301 (28)

120

The opaque backing shall be made from aluminum sheet having a minimum thickness of 0.50 mm (0.02 in.). The backing shall form an integral part of the delineator and shall retain the optical system securely. Mounting shall be provided by a single aluminum grommeted hole incorporated as part of the backing and shall be in the center of the reflector. The inside diameter of the grommet hole shall be 5 mm (3/16 in.).

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For qualification or approval of the manufacturer, 100 delineators of each color which the manufacturer proposes to supply shall be submitted for tests. The delineators shall pass the test to determine adequate seal in accordance with 913.10(e)2. After qualification or approval of the manufacturer, a type C certification in accordance with 916 will be required.

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(b) Reflective Sheeting Delineators. Single units shall consist of reflective sheeting affixed to an aluminum backplate. The unit shall be 75 mm by 200 mm (3 in. by 8 in.) in size, with a tolerance of " 3 mm (" 1/8 in.) for the white (silver) delineator. Each multiple unit, amber or interstate yellow, shall consist of reflective sheeting affixed to an aluminum backplate 125 mm by 125 mm (5 in. by 5 in.) square with a tolerance of " 3 mm (" 1/8 in.). The square unit shall be mounted as a diamond with one mounted at the top of the post and the other placed in a vertical row immediately below. The backplate shall be fabricated from sheet aluminum alloy 6061-T6 or 5154-H38, ASTM B 209M (ASTM B 209), with a minimum thickness of 1.626 mm (0.064 in.). Reflective sheeting shall be in accordance with 913.10(d)3.

Two mounting holes, 5 mm (3/16 in.) in diameter, shall be provided, one at the top and one at the bottom. The holes shall be 150 mm (6 in.) " 2 mm (1/16 in.) center to center. Holes shall be in the corners of the square units so as to mount as a diamond. The face of the unit shall be coated after the fabrication.

150 Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(c) Barrier Delineators. The delineators shall consist of a transparent acrylic plastic face, herein referred to as the lens, and an opaque back fused to the lens under heat and pressure around the entire perimeter to form a unit permanently sealed against dust, water, and water vapor. The reflector lens shall be colorless.

160 The lens shall consist of a smooth front surface free from projection or indentations other than for purposes of identification or orientation of the reflector. The rear surface shall have a prismatic configuration such that it will effect total internal reflection of light. The manufacturer's trademark shall be molded legibly into the face of the lens.

The reflector lens, having a minimum effective reflex area of 4194 mm² (6.5 in²), shall be methyl methacrylate in accordance with Federal Specification LP-380C, type 1, Class 3. Photometric or optical requirements shall equal or exceed the following minimum values:

Observation Angle Degrees	Entrance Angle Degrees	Specific Intensity lux (footcandles)	
		Clear	Yellow
0.1	0	1281 (119)	850 (79)
0.1	20	506 (47)	301 (28)

170 The entrance angle is the angle at the reflector between the direction of light incident on it and the direction of reflector axis. The observation angle is the angle at reflector between the observer's line of sight and direction of light incident on reflector. The specific intensity is the candlepower returned at the chosen observation angle by a reflector or reflective surface for each lux (footcandle) of illumination at the reflector.

Barrier delineators shall be initially approved for use with a type A certification and, if accepted, the product will be added to the Department's List of Approved Barrier Delineators. Following initial approval, material furnished under this specification shall be covered by a type C certification in accordance with 916.

180

913.09 Glass Beads. Glass beads shall be small spheroids manufactured from virgin or reclaimed glass. They shall be in accordance with the gradation set out below and, by reflection and refraction, improve the night visibility of traffic markings when they are applied in a suitable manner to the paint at the time it is applied. They shall be transparent and, in general, free from foreign matter. They shall not contain more than 25% defects which would cause the beads to be non-spherical or which would impair reflective properties as determined by testing according to ASTM D 1155 augmented by microscopic examination. Such defects include, but are not restricted to, milkiness, scratches, pits, air bubbles, fused beads, irregularities, and angularity.

The beads shall show an index of refraction of 1.50 or higher when tested in accordance with ITM No. 601, the liquid immersion method. They shall be in accordance with the following gradation when tested in accordance with ASTM D 1214, except sampling shall be as set out in the Manual for Frequency of Sampling and Testing, and a probe sampling device may be used to obtain a sample from the bag of beads.

Passing Sieve No.	Retained On Sieve No.	Percent	
		Minimum	Maximum
20 (850 :m)	30 (600 :m)	0	20
30 (600 :m)	50 (300 :m)	40	80
50 (300 :m)	80 (180 :m)	10	40
80 (180 :m)	—	0	5

A minimum of 0.9 kg (2 lb) of glass beads shall be placed in a clean, washed, cotton bag furnished by the supplier and shall be subject to a moisture test. The bag containing the sample shall be immersed in a container of water for 30 s or until the water covers the beads whichever is longer. The bag shall be removed and any excess water shall be forced from the sample by squeezing the bag. The bag shall be suspended and allowed to drain for 2 h at 21E to 22EC (70E to 72EF). At the end of this time, the sample shall be mixed in the bag by shaking the bag. The sample shall be slowly transferred to a clean, dry, standard glass funnel (Corning 6120). The entire sample shall flow through the funnel freely without stoppage. If the beads clog when first introduced into the funnel, it is permissible to tap the funnel lightly to initiate the flow.

From each shipment or batch at each point of delivery, a random sample of three 23 kg (50 lb) will be taken for testing and approval of the shipment or batch. The three bag sample will be taken so as to represent rack or pallet subdivisions comprising the shipment. Not more than one bag shall be selected from an individual rack or pallet. The entire shipment will be accepted or rejected on the basis of each bag in this sample meeting all requirements set out herein. Evidence of caking, foreign matter, or lumping on any sample selected at random and inspected at the point of delivery will be sufficient cause for rejection of the shipment. No shipment shall contain more than two batches of glass beads. A batch is defined for this purpose as the continuous production of glass beads for one day.

Beads shall be packaged in 23 kg (50 lb) standard waterproof bags. These bags shall be multi-walled, suitably stitched, and of sufficient strength to withstand shipping and handling without breaking. The bags shall be fabricated in a manner to provide easy opening. Each bag shall bear a label on which is shown the name and address of the manufacturer, net weight of contents, date of manufacture, batch or lot number, and rack or pallet number.

230 **913.10 Traffic Signs.** Traffic signs shall be designed to conform with applicable requirements of AASHTO Specifications for Highway Signs, Luminaries, and Traffic Signals, and the MUTCD. If there is a conflict for Interstate signs, the AASHTO requirements shall prevail.

Overlap or butt splicing of reflective sheeting by the sign fabricator is not permitted on panel signs. Splices as supplied on the roll of sheeting by the sheeting manufacturer, hereafter referred to as roll splices, are permitted subject to the following: a maximum of one roll splice per panel and a maximum of three roll splices per sign is permitted on a panel sign. Exit panels are considered as part of the signs they are attached to when fabricated under the same contract. If the exit panels are to be
240 made for separate installation, only one roll splice is permitted on the entire sign.

Overlap splices on sheet signs shall be permitted only because of insufficient sheeting width on signs whose smaller dimension exceeds 1220 mm (48 in.) The overlap splice shall be installed in a shingle-type manner using a horizontal lap. The lap width shall be a minimum of 6 mm (1/4 in.). Butt slices are not permitted by the fabricator. Roll splices are permitted on sheet signs but shall not exceed one splice per sign.

250 All signs shall be packed for shipment and handled during construction in accordance with 802.01. Any sign or sign face damaged prior to acceptance shall be replaced or repaired. If replacement is required the sheet signs shall be replaced in entirety and the panel signs shall have the affected panels replaced. Repairs to the reflective sheeting shall be in accordance with the manufacturers' recommendations.

Repaired areas on panel signs shall not be larger than 75 mm by 75 mm (3 in. by 3 in.). Repaired areas of 25 mm by 25 mm (1 in. by 1 in.) or less shall be limited to a maximum of 3 per panel and a maximum of 6 per panel sign. Repaired areas of larger than 25 mm by 25 mm (1 in. by 1 in.) but no more than 75 by 75 mm (3 in. by 3 in.) shall be limited to one per panel and a maximum of three per panel sign. Repaired areas
260 on a panel or on a panel sign shall be limited to the maximum number of small repaired areas and the maximum number of larger repaired areas or any combination thereof. No more than 20% of the total number of panel signs may be patched. Signs in excess of 20% shall have damaged panels replaced. Panels with sheeting cracked at the bend around the panel edge shall be replaced.

Repaired areas on sheet signs shall be less than 25 mm by 25 mm (1 in. by 1 in.) and shall be limited to one per sign. No more than 10% of the sheet signs may be patched. All damaged sheet signs in excess of 10% shall be replaced.

270 A sign with the metal face damaged greater than superficial deformation shall be replaced.

(a) Sheet Signs. The backing material for sheet signs may be made from sheet aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 5052H38, alloy 6061-T6; sheet steel in accordance with ASTM A 653M (ASTM A 653), grade A, stretcher leveled with an extra smooth commercial coating of the galvanized-bonderized process, and a minimum Rockwell hardness of 65; or fiberglass reinforced plastic in accordance with 913.10(g).

280 Temporary signs may be of aluminum, steel, or plywood, unless otherwise provided.

Fabrication, including cutting and punching of holes but excluding holes for demountable copy, shall be completed prior to surface treatment. Material shall be cut to size and shape and shall be free from buckles, warp, dents, cockles, burrs, and defects resulting from fabrication. The surface shall be essentially a plane surface.

290 Metal signs base material shall be given a preliminary cleaning with an alkaline cleanser or grease solvent. Aluminum shall be rinsed, etched, rinsed again, and dried. If zinc oxide is present on steel material, it shall be removed with phosphoric acid or an inhibited pickling solution and rinsed with running water followed by a hot water tank rinse if necessary. All dirt and loose phosphate coating shall be removed from steel material with a tac rag. The back, edges, and all areas of steel material not covered with reflective sheeting shall be primed with a high quality, non-chalking, short to medium, oil primer and then with a high quality, short to medium, oil enamel. Painted steel signs shall be finished, in the color specified, with baking enamel meeting Federal Specification TT-P-489B in accordance with recommendations of the paint manufacturer.

300 Surfaces of sign backing material to which reflective sheeting is to be applied shall be treated in accordance with recommendations of the reflective sheeting manufacturer.

310 The bolts used to attach the sheet signs to steel, flanged, channel posts shall be 8 mm by 75 mm (5/16 in. by 3 in.) hex head cap screw type, full thread USS 18 threads per 25 mm (in.), complete with hex nut. The flat steel washers shall be 8 mm (5/16 in.) inside diameter by 14 mm (9/16 in.) outside diameter, thickness 2 mm (1/16 in.). Bolts, nuts, flat washers, and lock washers shall be stainless steel or be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153, class C. flat plastic washers shall be 8 mm (5/16 in.) inside diameter by 22 mm (7/8 in.) outside diameter 0.81 mm (0.032 in.) thickness.

Materials for stainless steel bolts, nuts, flat washers, and lock washers shall be in accordance with ASTM A 276, type 304. Materials for galvanized bolts, nuts, flat washers, and lock washers shall be in accordance with ASTM A 307, grade A.

The number of posts for mounting and the minimum thickness or gage of the sheet shall be as shown for the appropriate sign width.

320

Width mm (in.)	Number of Posts	Thickness mm (in.) Aluminum Sheet	Gage Steel Sheet
Up to 610 (24)	1	2.0 (0.080)	18 (1.22 mm)
635 to 760 (25 to 30)	1	2.0 (0.080)	18 (1.22 mm)
790 to 1525 (31 to 60)	2	2.50 (0.100)	16 (1.5 mm)
1550 and over (61 and over)	2	3.20 (0.125)	15 (1.9 mm)

(b) Panel Signs. Aluminum extruded panels shall be in accordance with ASTM B 221M (ASTM B 221), alloy 6063-T6, and be 230 or 305 mm (9 in. or 12 in.) in width. Extruded aluminum panels shall be flat and straight within tolerances established by the aluminum industry. Typical weights per meter (linear foot) for panels shall be: 230 mm (9 in.), 0.28 kg (2.00 lb); or 305 mm (12 in.), 0.34 kg (2.48 lb). Aluminum post clips shall be in accordance with ASTM B 26M (ASTM B 26) or B 108, alloy 356.0-T6, and be placed in accordance with the following sign width classifications:

330

1. Up to and including 7.30 m (24 ft), clips shall be placed on both sides of each post at the top and bottom of the sign. Intermediate clips shall be placed one on each panel on each post and shall alternate left to right on each post.
2. Over 7.30 m (24 ft), double clips shall be used, one on the right side and one on the left side on each post per panel width, plus the sets necessary to attach the top and bottom of the sign.

340

Aluminum post clip bolts shall be 10 mm by 44 mm (3/8 in. by 1 3/4 in.) by 44 mm (1 3/4 in.) 16 NC threaded, ASTM B 211M (ASTM B 211), alloy 2024-T4, with 10 mm (3/8 in.) 16 NC threaded lock nuts, ASTM B 211M (ASTM B 211), alloy 2017-T4. Lock nuts shall be torqued two full turns beyond snug fit. Washers shall be flat, ASTM B 209M (ASTM B 209), alloy Alclad 2024-T4. Panel bolts shall be 10 mm by 19 mm (3/8 in. by 3/4 in.) 16NC threaded, ASTM B 211M (ASTM B 211), alloy 2024-T4, with 10 mm (3/8 in.) 16 NC threaded standard hex nuts, ASTM B 211M (ASTM B 211), alloy 6061-T6.

Formed steel panels shall be in accordance with 912.10(a) for sheet steel, shall be 150 mm (6 in.) to 305 mm (12 in.) in width, and shall be 1.5 mm (16 gage) and have a flatness of 0.24 mm per m (1/32 in. per ft) of length and 0.1 mm per mm (0.004 in. per in.) of width. Post clips shall be of 5 mm (3/16 in.) steel plate or bar of structural quality in accordance with ASTM A 36M (ASTM A 36). They shall be hot dip galvanized after fabrication in accordance with ASTM A 153. The clips shall be 50 mm (2 in.) wide by 75 mm (3 in.) long. They shall be formed in an arc along the long dimension, with a rise between the arc and the chord of 8 mm (5/16 in.). There shall be a slot 10 mm by 19 mm (3/8 in. by 3/4 in.) with the 19 mm (3/4 in.) dimension along the 75 mm (3 in.) centerline. Post clip bolts shall be J-bolts, stainless steel, type 305 or 304, 9 mm by 50 mm (5/16 in. by 2 in.) 18 NC threads with 10 mm (3/8 in.) stainless steel flat and lock washers, and 8 mm (5/16 in.) 18 NC threaded hex nuts. Other fasteners may be substituted if approved. Spacing of these fasteners shall be the same as set out above for the extruded aluminum panels. Panel bolts shall be stainless steel 10 mm by 19 mm (3/8 in. by 3/4 in.) 16 NC threaded with stainless steel flat washers and hex nuts.

Trim molding shall be of the same material and gage as the panels to which it is attached.

Surface preparation shall be in accordance with 913.10(a) for metal signs. 150 mm (6 in.) sections shall be used at the top or bottom of the sign to make up signs not conforming to 0.3 m (1 ft) modules. Panels shall be bolted together on 610 mm (24 in.) centers with an allowable gap of no more than 2 mm (1/16 in.) between units. Panels shall be braced with suitable metal angles or 50 by 100 mm (2 by 4 in.) wood supports, which shall be removed after signs have been erected. Surface preparation for plywood signs shall be in accordance with the paint or reflective sheeting manufacturer's recommendations.

(c) Flexible Roll-Up Prismatic Reflective Sign. The flexible roll up prismatic reflective sign shall consist of a vinyl microprism reflective sheeting heat sealed, in a grid pattern not to exceed 32 mm (1 1/4 in.), to a vinyl coated fabric backing with a cross brace assembly and attaching fasteners. The reflective face and backing shall both be ultraviolet light stabilized and of the same color.

1. Reflectivity. The prismatic reflective sheeting shall have the following minimum reflective intensity values at 0.2 of a degree and 0.5 of a degree divergence expressed as average candelas per lux per square meter (candlepower per footcandle per square foot) of material. Measurements shall be conducted in accordance with ASTM E 809 with a test distance of 15 m (50 ft), at entrance angles of -4 and 30 degrees, and a photoreceptor angular aperture and source angular aperture of 0.1 of a degree. Projector exit aperture shall be a circle with a diameter of 25 mm (1 in.). Retroreflector reference center shall be the center of the sample tested, and retroreflector reference angle shall be 90 degrees. The datum mark shall be placed in accordance with the manufacturer's instructions.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
PRISMATIC REFLECTIVE SHEETING**

Divergence Angle (E)	Incidence Angle (E)	Orange
0.2	-4	70
0.2	+ 30	30
0.5	-4	50
0.5	+ 30	17

2. Color. The diffused day value of the orange sheeting shall be determined in accordance with 913.10(d)1b, except the sheeting shall have a minimum Y Reflectance Limit of 8.0.

3. Sheeting. The reflective sheeting shall consist of corner cube prismatic elements bonded to a flexible transparent weatherproof plastic having a smooth surface and encapsulated by a protective plastic backing. The sheeting shall contain no less than 6,200 microscopic cube corner prisms per 100 mm² (40,000 prisms per sq in.). The reflective sheeting shall have an 85 degree specular gloss of not less than 175 when tested in accordance with ASTM D 523.

The sheeting shall permit color processing with compatible transparent and opaque process inks at temperatures of 16EC to 39EC (60EF to 100EF) and relative humidity at 20% to 80%. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures as recommended by the manufacturer.

The sheeting, conditioned for 24 h at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity, shall be sufficiently flexible to show no cracking when bent within 1 s around a 3 mm (1/8 in.) mandrel with backing contacting the mandrel.

The sheeting shall have a minimum tensile strength of 1.8 MPa (260 psi) and a minimum modulus of elasticity of 11.0 MPa (1,600 psi) when tested in accordance with ASTM D 882.

4. Durability. The reflective material shall be weather resistant and, following cleaning, shall show no appreciable discoloration, cracking, blistering, or dimensional change and shall not have less than 70% of the specified minimum reflective intensity values when subjected to accelerated weathering for 250 h, in accordance with ASTM G 23, method 1, with humidity off, using type E or EH apparatus. Colorfastness shall be in accordance with 912.10(d)1e.

5. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

6. Sign Face Backing Fabric. The backing fabric used to produce flexible roll-up reflective signs shall be coated on both sides with polyvinyl chloride or other approved material of the same color as the sign face. The backing fabric shall meet the following minimum requirements:

- a. A base fabric shall have a fiber of 1,000 Denier polyester; a weight of 102 g/m² (3 oz. per sq yd); and a fabric count of 10 warp and 10 fill.
- b. A coated fabric shall have a total weight of 492 g/m² (14.5 oz. per sq yd) and a distribution of 60 face and 40 back.
- c. The mechanical properties shall be tested in accordance with Federal Standard 191, method 5100. The test results shall be as follows:

	Warp	Fill
Tensile Strength (grab lbs)	Min. 980 N (220 grab lbs)	Min. 712 N (160 grab lbs)
Elongation at break (7%)	Min. 30	Min. 26

7. Cross Brace Assembly and Attaching Fasteners. Cross braces shall be constructed of glass reinforced resin or other suitable material to provide enough strength for the sign to withstand 64 km/hr (40 mph) winds without causing sign material to distort enough to affect legibility of the sign. Cross brace material shall be ultraviolet light stabilized.

Cross brace ends must be rounded to prevent splintering, sharp edges or damage to sign face. Cross braces shall be fastened at their centers with a suitable connector. The two braces must be separated by a flat washer or other approved separating hardware. The head of the bolt which holds the braces at the center shall face the sign.

The cross braces shall be attached to the back of the flexible roll-up sign with fasteners made of corrosion resistant material by means that shall allow as flat a profile as possible. A cross brace fastener shall be located in each of the four corners.

8. General Characteristics and Packaging. The flexible roll up prismatic reflective signs shall be of good appearance, free from ragged edges, cracks, and extraneous materials. A maximum of one splice is permitted in the reflective sheeting material and no splices are permitted in the fiber backing material in each roll-up sign. All splices on the fabricated roll-up signs shall be suitable for processing as supplied. Wrinkling, streaking, and mottling apparent under normal viewing conditions will not be permitted.

The roll-up signs stored in accordance with manufacturer's instructions shall be suitable for use at least one year after purchase without degradation in color and retroreflectance.

Completed signs shall be packaged in accordance with commercially accepted standards.

480 **9. Basis of Use.** Material furnished under this specification shall be covered by a type C certification in accordance with 916.

(d) Reflective Sheeting. Three types of reflective sheeting shall be used for signs and channelizing devices. Enclosed lens (engineer grade) and encapsulated lens (high intensity) reflective sheeting shall be used on signs and delineators, and barricades. flexible encapsulated lens reflective sheeting shall be used on plastic drums, flexible delineator posts, and other flexible channelizers.

490 **1. General.** Reflective sheeting shall consist of spherical lens elements within a transparent plastic having a smooth, flat surface. The sheeting shall be weather resistant and have a protected precoated adhesive backing.

a. Reflectivity. Reflective sheeting shall have minimum specified reflective intensity values for the respective type of sheeting at 0.2 degree and 0.5 degree divergence expressed as average candelas per lux per square meter (candlepower per footcandle per square foot) of material. Measurements shall be conducted in accordance with standard testing procedures for reflex reflectors in accordance with Federal Specifications L-S-300C, "Sheeting and Tape, Reflective, Non-exposed Lens, Adhesive Backing".

500 The primary color of the reflective background sheeting on certain signs shall be accomplished by the reverse screen method whereby a transparent colored ink is applied in a thin film to the face of white reflective sheeting to produce the reflectorized background color. When reverse screened transparent colored inks are applied over reflective sheeting, the reflective intensity value for enclosed lens reflective sheeting shall be at least the value listed as the minimum for the manufactured color. For all other types of sheeting, the reflective intensity value shall be at least 70% of the value listed for the manufactured color. Reversed screen processing shall be accomplished with inks and procedures as recommended by the manufacturer of the sheeting used.

510 **b. Color.** The diffuse day color of the reflective sheeting shall be determined in accordance with ASTM E 97. Colors shall be in accordance with Table 2. Geometric characteristics shall be confined to illumination incident within 10 degrees of and centered about a direction 45 degrees from the perpendicular to the test surface and viewing shall be within 15 degrees of and centered about the perpendicular to the test surface. Conditions of illumination and observation shall not be interchanged. The test apparatus shall be calibrated and standardized in accordance with the manufacturer's recommended procedure.

520 **c. Adhesive.** The reflective sheeting shall include a precoated, pressure sensitive adhesive backing, Class 1, or a tack free, heat activated adhesive backing, Class 2, either of which may be applied without necessity of additional adhesive coats on either the reflective sheeting or application surface.

530 The Class 1 adhesive backing shall be a pressure sensitive adhesive of the aggressive tack type requiring no heat, solvent or other preparation for adhesion to smooth clean surfaces. The Class 2 adhesive backing shall be a tack free adhesive activated by applying heat in excess of 80EC (175EF) to the material as in the heat vacuum process of sign fabrication, requiring no solvent or additional preparation to smooth clean surfaces.

 The protective liner attached to the adhesive shall be removed by peeling without soaking in water or other solvents without breaking, tearing, or removing any adhesive from the backing. The protective liner shall be easily removed following accelerated storage for 4 h at 71EC (160EF) under a weight of 17.2 kPa (2.5 psi).

540 When applied to a smooth aluminum surface and tested as specified in Federal Specification L-S-300C, Paragraph 4.4.4., the adhesive backing of the reflective sheeting shall produce a bond to support a 0.8 kg (1 3/4 lbs) weight for 5 min without the bond peeling for a distance of more than 50 mm (2 in.).

d. Sheeting. The sheeting shall permit cutting and color processing with compatible transparent and opaque process inks at temperatures of 16EC to 38EC (60EF to 100EF) and relative humidity at 20% to 80%. The sheeting shall be heat resistant and permit force curing without staining of applied or unapplied sheeting at temperatures as recommended by the manufacturer.

550 A 230 by 230 mm (9 in. by 9 in.) reflective sheeting specimen with liner shall be conditioned a minimum of 1 h at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity. The liner shall be removed and the specimen placed on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 h, the specimen shall be measured to determine the amount of dimensional change. The reflective sheeting shall not shrink in any dimension more than 0.8 mm (1/32 in.) in 10 min nor more than 3 mm (1/8 in.) in 4 h. The reflective sheeting shall possess stable and durable spherical lens elements which, following extraction, shall show no deterioration following submersion in a 5N solution of sulfuric acid for 30 min at 22E " 1EC (72E " 2EF).

560 **e. Durability.** Reflective material shall be weather resistant and following cleaning, shall show no appreciable discoloration, cracking, blistering, or dimensional change.

One of the specimens prepared and subjected to accelerated weathering shall be used to test for colorfastness. Wet the specimen with a mild detergent and water solution and compare it visually with a similarly treated unexposed specimen under natural, North Sky daylight, or artificial daylight having a color temperature of 7500 K. The colorfastness will be evaluated as follows:

- 570 Excellent **C** No appreciable change in color.
 Good **C** Perceptible, but no appreciable change in color.
 Fair **C** Appreciable change in color.

Appreciable change in color means a change that is immediately noticeable in comparing the exposed specimen with the original comparison specimen. If closer inspection or a change of angle of light is required to make apparent a slight change in color, the change is not appreciable. The reflective material must show good colorfastness, or better.

- 580 The sheeting surface of sign background shall be refurbished in the following manner. Preparation shall include the removal of all demountable copy and legends within the sign border. Cleaning shall accomplish the removal of all foreign material from the sheeting surface. If patching of the sheeting is required, this will be accomplished prior to the clear coating. All copy and legends shall be remounted after the clear coating.

- 590 **f. Impact Resistance.** A test specimen shall be prepared by applying sheeting material according to the manufacturer's recommendations to a cleaned, etched 1 mm by 75 mm by 125 mm (0.040 in. by 3 in. by 5 in.) panel of aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. The specimen shall be conditioned for 24 h at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity. It shall show no cracking when the face of the panel is subjected to an impact of a 0.9 kg (2.0 lb) weight with a 16 mm (5/8 in.) rounded tip dropped from a 1.3 N m (10 inch pound) setting on a Gardner Variable Impact Tester, 1G-1120.

- 600 **g. General Characteristics and Packaging.** The reflective sheeting as supplied shall be free from ragged edges, cracks, extraneous materials, and shall be furnished in either rolls or sheets. When the reflective sheeting is furnished in continuous rolls, the average number of splices shall be no more than three per 46 m (50 yd) of material with a maximum of four splices in any 46 m (50 yd) length. Splices shall be suitable for continuous application.

Rolls shall be packed snugly in corrugated fiberboard boxes in such manner that no damage or defacement may occur to the reflective sheeting during shipment or storage. Rolls 75 mm (3 in.) in width to 305 mm (12 in.) in width shall be packed in corrugated fiberboard cartons of minimum 91 kg (200 lb) test. Rolls 330 mm (13 in.) in width to 600 mm (24 in.) in width shall be packed in corrugated fiberboard cartons of 125 kg (275 lbs) test. Rolls 635 mm (25 in.) in width and above shall be packed in corrugated fiberboard cartons of minimum 160 kg (350 lbs) test. Rolls wider than 150 mm (6 in.) and 9 m (10 yd) or longer in length shall be supported and suspended by the roll core within the cartons by means of plugs within built up and reinforced corrugated pads. Cut sheets shall be packaged flat between pressed composition boards or corrugated pads of the same dimensions as the sheets and shall be so packed as to prevent damage or defacement during shipment or storage.

Stored under normal conditions, the reflective sheeting shall be suitable for use for a period of at least one year.

2. Enclosed Lens, Engineer Grade, and Super Engineer Grade, Reflective Sheeting. The sheeting shall consist of spherical lens elements embedded within a transparent plastic having a smooth, flat surface. The sheeting shall be weather resistant and have a protected precoated adhesive backing.

a. Reflectivity. The reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR ENCLOSED
ENGINEERED GRADE LENS SHEETING**

Divergence Angle (E)	Incidence Angle (E)	White	Green	Yellow	Red	Orange	Blue	Brown
.2	-4	70	9	50	14.5	25	4.0	1
0.2	+ 30	30	3.5	22	6	7	1.7	0.3
0.5	-4	30	4.5	25	7.5	13.5	2	0.35
0.5	+ 30	15	2.2	13	3	4	0.8	0.20

SUPER ENGINEER GRADE

Divergence Angle (E)	Incidence Angle (E)	White	Green	Yellow	Red	Orange	Blue	Brown
0.2	-4	140	30	100	30	60	10	5
0.2	+ 30	60	10	36	12	22	4	2
0.5	-4	50	9	33	10	20	3	2
0.5	+ 30	28	6	20	6	12	2	1

b. Color. The diffuse day value of the sheeting shall be determined in accordance with 913.10(d)1b.

**TABLE 1 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCLOSED LENS SHEETING**

	Chromaticity Coordinates (Corner Points)							
	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
Silver-White	.305	.290	.350	.342	.321	.361	.276	.308
Yellow	.482	.450	.532	.465	.505	.494	.475	.485
Red	.602	.317	.664	.336	.644	.356	.575	.356
Green	.130	.369	.180	.391	.155	.460	.107	.439
Blue	.147	.075	.175	.091	.176	.151	.106	.113
Orange	.535	.375	.607	.393	.582	.417	.535	.399
Brown	.445	.353	.604	.396	.556	.443	.445	.386

**TABLE 1 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCLOSED LENS SHEETING**

	Reflectance Limit		Ref. Std. MUNSELL PAPERS
	Y		
	Min.	Max.	
Silver-White	35.0		6.3GY 6.77/0.8
Yellow	29.0	45.0	1.25Y 6/12
Red	8.0	12.0	8.2R 3.78/14.0
Green	3.5	9.0	0.65BG 2.84/8.45
Blue	1.0	4.0	5.8PB 1.32/6.8
Orange	18.0	30.0	2.5YR 5.5/14.0
Brown	4.0	9.0	5YR 3.6

640

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 40 when tested in accordance with ASTM D 534.

A test specimen shall be prepared by applying sheeting according to the manufacturer's recommendations to a clean, etched 0.51 by 50 by 200 mm (0.020 in. by 2 in. by 8 in.) panel of aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. The specimen shall be conditioned a minimum of 48 h and tested at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity. It shall show no cracking when bent around a 19 mm (3/4 in.) mandrel.

650

e. Durability. Reflective material shall not have less than 50% of the specified minimum reflective intensity values for enclosed lens sheeting when subjected to accelerated weathering for 1000 h in accordance with ASTM G 23, method 1 with humidity off, using type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, method 6151, Paragraph 4.1.1.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. The general characteristics and packaging shall be in accordance with 913.10(d)1g.

3. Encapsulated Lens, High Intensity, Reflective Sheeting. The high intensity reflective sheeting shall consist of spherical lens elements adhered to a synthetic resin and encapsulated by a flexible, transparent, weatherproof plastic having a smooth surface. The sheeting shall have a precoated adhesive backing protected by a treated plastic liner.

a. Reflectivity. The high intensity reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
ENCAPSULATED LENS SHEETING**

Divergence Angle (E)	Incidence Angle (E)	White	Green	Yellow	Red	Orange	Blue
0.2	-4	250	45	170	45	100	20
0.2	+30	150	25	100	25	60	11
0.5	-4	95	15	62	15	30	7.5
0.5	+30	65	10	45	10	25	5

Reflective sheeting for all sign copy, including letters, numerals, symbols, borders, and route markers used on high intensity reflective sheeting background, shall be high intensity white.

b. Color. The diffuse day value of the sheeting shall be determined in accordance with 913.10(d)1b, except the sheeting shall be in accordance with Table 2.

**TABLE 2 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR REFLECTIVE SHEETING**

	Chromaticity Coordinates (Corner Points)							
	1		2		3		4	
	X	Y	X	Y	X	Y	X	Y
White	.303	.287	.368	.353	.340	.380	.274	.316
Green	.030	.380	.166	.346	.286	.428	.201	.776
Yellow	.498	.412	.557	.442	.479	.520	.438	.472
Red	.613	.297	.708	.292	.636	.364	.558	.352
Orange	.550	.360	.630	.370	.581	.418	.516	.394
Blue	.144	.030	.244	.202	.190	.247	.066	.208
Brown	.430	.340	.610	.390	.550	.450	.430	.390

**TABLE 2 - COLOR SPECIFICATIONS LIMITS AND REFERENCE
STANDARDS FOR ENCAPSULATED LENS SHEETING**

	Reflectance Limit		Ref. Std. MUNSELL PAPERS
	Min.	Max.	
White	27.0		5PB 7/1
Green	3.0	9.0	10G 3/8
Yellow	15.0	45.0	1.25Y 6/12
Red	2.5	15.0	7.5R 3/12
Orange	7.0	30.0	2.5YR 5.5/14
Blue	1.0	10.0	5.8PB 1.32/6.8
Brown	1.0	9.0	5YR 3/6

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 50 when tested in accordance with ASTM D 523.

Color processing for encapsulated lens material shall be restricted to sheeting with heat activated adhesive backing unless otherwise recommended by the manufacturer.

The sheeting with the liner removed and conditioned for 24 h at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity, shall be sufficiently flexible to show no cracking when bent within 1 s around a 3 mm (1/8 in.) mandrel with adhesive contacting the mandrel.

e. Durability. All colors of the reflective material, except orange, shall have not less than 80% of the specified minimum intensity values for encapsulated lens sheeting when subjected to accelerated weathering for 2200 h in accordance with ASTM G 23, method 1 with humidity off, using Type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, method 6151, Paragraph 4.1.1. Orange reflective sheeting shall conform to the same requirements, except the accelerated weathering shall be 500 h instead of 2200 h. Colorfastness shall be in accordance with 913.10(d)1e.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. Wrinkling, streaking and mottling apparent under normal viewing conditions will not be permitted.

4. Flexible Encapsulated Lens Reflective Sheeting, High Intensity. This sheeting shall be for use on flexible delineating or channelizing devices where flexing and bending is anticipated. The description of this sheeting shall be in accordance with 913.10(d)3.

a. Reflectivity. The reflectivity shall be in accordance with 913.10(d)3a.

b. Color. The color shall be in accordance with 913.10(d)3b.

730 **c. Adhesive.** The adhesive shall be a pressure sensitive adhesive, Class 1 in accordance with 913.10(d)1c, except the adhesive backing of the flexible reflective sheeting shall produce a bond to support a 0.8 kg (1 3/4 lb) weight for 5 min, without the bond peeling for a distance of more than 25 mm (1.0 in.) when applied to a smooth aluminum surface and tested as specified in Federal Specifications L-S-300C, Paragraph 4.4.4.

d. Sheeting. The sheeting shall be in accordance with 913.10(d)3d with the exception of the following:

740 (1) A 229 mm by 229 mm (9 in. by 9 in.) reflective sheeting specimen with liner shall be conditioned a minimum of 1 h at 22E " 1EC (72E " 2EF) and 50% " 5% relative humidity. The liner shall be removed and the specimen placed on a flat surface with the adhesive side up. Ten minutes after the liner is removed and again after 24 h, the specimen shall be measured to determine the amount of dimensional change. The reflective sheeting shall not shrink in any dimension more than 0.8 mm (1/32 in.) in 10 min nor more than 2.5 mm (1/10 in.) in 24 h.

750 (2) The sheeting, with the liner removed and conditioned for 24 h at -18E " 1EC (0E " 2EF) and 50% " 5% relative humidity, shall be sufficiently flexible to show no cracking when bent within 1 s around a 1/8 of an inch (3.2 mm) mandrel with adhesive contacting the mandrel.

760 **e. Durability.** All colors of the flexible reflective material shall have a minimum 70% of the specified minimum intensity values for encapsulated lens reflective sheeting when subjected to accelerated weathering for 500 h in accordance with ASTM G 23, method 1 with humidity off, using type E or EH apparatus. Colorfastness shall be in accordance with 913.10(d)1e.

f. Impact Resistance. Impact resistance shall be in accordance with 912.10(d)1f, except the flexible reflective sheeting shall be conditioned at 0E " 2EF (-18E " 1EC) and 50% " 5% relative humidity prior to impact testing.

g. General Characteristics and Packaging. The flexible reflective sheeting and packaging shall be in accordance with 912.10(d)3g.

5. Prismatic Lens, High Intensity, Reflective Sheeting. Prismatic lens high intensity reflective sheeting shall consist of prismatic lens elements which shall be adhered and formed in a transparent synthetic resin, sealed, and backed with a pressure-sensitive adhesive and a plastic liner.

a. Reflectivity. The prismatic lens reflective sheeting shall have the following minimum reflective intensity values.

**MINIMUM REFLECTIVE INTENSITY VALUES FOR
PRISMATIC LENS SHEETING**

Divergence Angle, Deg.	Incidence Angle, Deg.	White	Green	Yellow	Red	Orange	Blue	Brown
0.1	-4	400	56	270	56	160	32	12
0.1	+ 30	120	13	75	13	48	7	3
0.2	-4	250	35	170	35	100	20	7
0.2	+ 30	80	9	54	9	34	5	2
0.5	-4	135	17	100	17	64	10	4
0.5	+ 30	55	6.5	37	6.5	22	3.5	1.4

b. Color. The diffused day value of the sheeting shall be determined in accordance with 913.10(d)1b. The sheeting shall be in accordance with Table 2.

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The 85 degree specular gloss of the reflective sheeting shall be a minimum of 50 when tested in accordance with ASTM D 523.

Color processing for the sheeting shall permit cutting and color processing with compatible transparent and opaque process colors in accordance with the sheeting manufacturer's recommendations at temperatures of 15EC to 38EC (59EF to 100EF) and relative humidities of 20% to 80%. The sheeting shall be heat resistant and shall permit force curing without staining of applied or unapplied sheeting at temperatures recommended by the sheeting manufacturer.

The sheeting, with the liner removed and conditioned for 24 h at 22EC " 1EC (72EF " 2EF) and 50% " 5% relative humidity, shall be sufficiently flexible to show no cracking when bent within 1 s around a 3 mm 1/8 in.) mandrel with adhesive contacting the mandrel.

e. Durability. The durability shall be in accordance with 913.10(d)3e.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. Wrinkling, streaking, and mottling which are apparent under normal viewing conditions will not be permitted.

6. Prismatic Lens, Super High Intensity, Reflective Sheeting. Prismatic lens super high intensity reflective sheeting shall consist of cube corner prismatic lens elements which shall be adhered and formed in a transparent synthetic resin, sealed, and backed with a pressure-sensitive adhesive and a plastic liner.

a. Reflectivity. The prismatic lens reflective sheeting shall have the following minimum reflective intensity values.

Divergence Angle, Deg.	Incidence Angle, Deg.	White	Green	Yellow	Red	Orange	Blue
0.2	-4	800	80	660	215	200	43
0.2	+30	400	35	340	100	120	20
0.5	-4	200	20	160	45	80	9.8
0.5	+30	100	10	85	26	50	5.0

b. Color. The diffused day value of the sheeting shall be determined in accordance with 913.10(d)1b. The sheeting shall be in accordance with Table 2.

c. Adhesive. The adhesive shall be in accordance with 913.10(d)1c.

d. Sheeting. The sheeting shall be in accordance with 913.10(d)5d.

e. Durability. All colors for reflective material, except orange, shall have not less than 50% of the specified minimum intensity value for prismatic lens sheeting when subjected to accelerated weathering for 2,200 h in accordance with ASTM G 23, Method 1 with humidity off, using type E or EH apparatus, and operation schedule of Federal Test Method Standard 141a, Method 6151, Paragraph 4.1.1. Orange reflective sheeting shall be in accordance with the same requirements. However, the accelerated weathering shall be 1,000 h instead of 2,200 h. Colorfastness shall be in accordance with 913.10(d)1e.

f. Impact Resistance. Impact resistance shall be in accordance with 913.10(d)1f.

g. General Characteristics and Packaging. Wrinkling, streaking, and mottling which are apparent under normal viewing conditions will not be permitted.

(e) Letters, Numerals, Symbols, and Accessories.

840

1. Embossed Reflective Sheeting Type. Embossed reflective sheeting type shall be in accordance with the AASHTO standards for use on the National System of Interstate and Defense Highways. The reflective sheeting shall be mechanically applied to the properly prepared aluminum with the equipment and in a manner prescribed by the sheeting manufacturer. Letters, numerals, and symbols shall be 1.02 mm (0.040 in.) thick aluminum sheets in accordance with ASTM B 209M (ASTM B 209), alloy 3003-H14. Borders shall be 0.81 mm (0.032 in.) thick aluminum sheet in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6. All units shall have an embossed height of approximately 3 mm (1/8 in.). Spacing of mounting holes for screws, bolts, or rivets shall be determined by character size and shape but in no case shall not be more than 20 mm (8 in.) on center.

850

Completed demountable units shall be dip coated with a full glossy coat of finishing clear as specified and supplied by the sheeting manufacturer. The finished units shall show careful workmanship and be clean cut, sharp, and have essentially a plane surface.

860

2. Acrylic Plastic Type. Acrylic plastic type shall consist of embossed aluminum frames in which prismatic reflectors are installed so as to be an integral part of the character or otherwise affixed to prevent their displacement in handling or service. Reflectors which are held in the frames by means of tape or adhesive will not be accepted. All units shall be in accordance with AASHTO standards for use on the National System of Interstate and Defense Highways. All items shall be fabricated from 1 mm (0.040 in.) sheet aluminum in accordance with, ASTM B 209M (ASTM B 209), alloy 3003-H14. Mounting holes shall be provided within the frames to permit the use of screws, rivets, or other common fasteners. The size and spacing of reflector holes shall be such as to afford maximum night legibility and visibility to the finished cut-out figure.

870

The reflectors shall consist of a clear and transparent plastic face, herein referred to as the lens, and an opaque back fused to the lens, under heat and pressure, around the entire perimeter to form a homogeneous unit permanently sealed against dust, water, and water vapor. The reflector shall be colorless, yellow, red, or green, as specified. The lens shall consist of a smooth front surface free from projections or indentations other than for identification and a rear surface bearing a prismatic configuration such that it will effect total internal reflection of light. The manufacturer's trademark shall be molded legibly into the face of the lens.

880 The specific brightness 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. Five reflectors shall be submitted for test for brightness. Area of the reflector will be calculated on the exposed surface within the frame. Failure of one or more subjected to test shall constitute failure of the lot.

Observation Angle, Degrees	Entrance Angle, Degrees	Specified Brightness candela per m ² per lux (candlepower per in. ² per footcandle)
1/10	0	2016 (14.0)
1/10	20	806 (5.6)
1/6	0	1440 (10.0)
1/6	20	576 (4.0)
1/3	0	1008 (7.0)
1/3	20	403 (2.8)

For yellow reflectors the specific brightness minimum shall be 60%. For red and green it shall be 25% of the value shown for crystal.

890 The following test shall be used to determine if a reflector is adequately sealed against dust and water. Submerge five samples in a water bath at room temperature. Subject the submerged samples to a vacuum of 125 mm (5 in.) of mercury, gage, for 5 min. Release the vacuum and let samples stand submerged for another 5 min. Remove samples and examine for water intake. Failure of one or more shall constitute failure of the lot. Three reflectors shall be tested for 4 h in a circulating air oven at 52E " 3EC (125E" 5EF). The test specimens shall be placed in a horizontal position on a grid or perforated shelf permitting free air circulation. At the conclusion of the test the samples shall be removed from the oven and permitted to cool in air to room temperature. The samples, after exposure to heat, shall show no significant change in shape and general appearance when compared with unexposed control standards. No failure will be permitted. The assembled cut out letter, symbol, or accessory shall withstand the combined corrosion test in accordance with ASTM B 117.

Each cut out figure, completely assembled with reflectors, shall be supplied in an individual package with contents marked thereon.

910 **(f) Fiberglass Reinforced Plastic Sign Panels.** Fiberglass reinforced plastic sign panels will be permitted as an alternate to aluminum sign panels up to and including a thickness of 2.54 mm (0.100 in.). The sign size will be limited to a maximum of 1220 mm by 1220 mm (48 in. by 48 in.). Fiberglass reinforced plastic shall be new and shall be in accordance with the requirements herein.

Fiberglass reinforced plastic sign panel material shall be a fiberglass reinforced thermoset polyester laminate. The panel shall be acrylic modified and UV stabilized for outdoor weatherability. The panel shall be stabilized to prevent the release of migrating constituents such as solvents or monomers over time. The panel shall contain no residual release agents on the surface of the laminate so that neither migrating constituents nor release agents shall be present in amounts that interfere with the bonding between the laminate and the reflective sheeting. The panel shall not contain visible cracks, pinholes, foreign inclusions, or surface wrinkles which affect the designed purpose or implied performance, alter the specific dimensions, or otherwise affect the serviceability.

1. Mechanical Properties. The following mechanical properties will be minimum requirements and shall be measured in both the line direction of the panel and at 90 degrees to the line as noted in the referenced ASTM test.

Mechanical Properties	Minimum Requirement, Mpa (psi)	ASTM Test
Tensile Strength	70 MPa (10,000)	D 638M (D 638)
Tensile Modulus	8275MPa (1,200,000)	B 638
Flexural Strength	138 MPa (20,000)	D 790M (D 790)
Flexural Modulus	8275 MPa (1,200,000)	D 790M (D 790)
Compression Strength	220 MPa (32,000)	D 695M (D 695)
Compression Modulus	9650 MPa (1,400,000)	D 695M (D 695)
Punch Shear	890 MPa (13,000)	D 732

2. Physical Properties. Fiberglass reinforced plastic panels shall be in accordance with physical properties shown below.

a. Thickness. The panel shall be 3.43 mm (0.135 in.) thick with a tolerance of " 0.13 mm (" 0.005 in.).

b. Length and Width. Panels shall be measured in accordance with ASTM D 3841 for the purpose of determining this physical property. The tolerance for each panel length and width shown in the Schedule of Pay Items shall be in accordance with the requirements as follows:

(1) Panel Length of 3660 mm (144 in.) or Less. The tolerance shall be " 3 mm (" 1/8 in.) of the nominal length.

(2) Panel Length Exceeding 3660 mm (144 in.). The tolerance shall be " 3 mm (" 1/8 in.) per 3.7 m (12 ft) increment of length, " 3 mm (" 1/8 in.) per remaining incremental length of less than 3.7 m (12 ft).

(3) Panel Width of 3660 mm (144 in.) or Less. The tolerance shall be " 3 mm (" 1/8 in.) of nominal width.

950 **c. Squareness.** The panel shall be within " 3 mm (" 1/8 in.) of square per 3.7 m (12 ft) of length when measured in accordance with ASTM D 3841.

d. Weather Resistance. The panel shall be classified as a minimum grade II weather resistant panel as specified in ASTM D 3841 following a 3,000 h " 100 h weatherometer test.

e. Fire Resistance. The extent of burning of the panel shall not exceed 25 mm (1.0 in.) when tested in accordance with ASTM D 635.

960 **f. Impact Resistance.** The panel shall resist the impact of a 0. 54 kg (1.18 lb) ball dropped from 18.3 m (60 ft) in accordance with ASTM D 3841.

g. Coefficient of Linear Thermal Expansion. The panel strength and impact resistance shall not be affected over a temperature range of - 54EC to 100EC (- 65EF to 212EF). The panels shall have a maximum coefficient of linear thermal expansion of 0.000306 mm/mm/EC (0.000018 in./in./EF) when tested in accordance with ASTM D 696.

970 **h. Panel Smoothness.** The panel shall be manufactured with smooth surfaces on both the top and bottom of the panel.

i. Flatness. Panels shall have a maximum deflection of 13 mm (0.5 in.) when tested as shown below.

(1) Test Purpose. This test shall be performed to determine the potential for warpage in fiberglass reinforced plastic panels.

980 **(2) Test Procedure.** This test will require five 760 mm by 760 mm (30 in. by 30 in.) fiberglass reinforced panels. Initial warpage shall be measured in four directions: 0 degrees, 45 degrees, 90 degrees, and 135 degrees. To measure warpage, the panel shall be freely suspended at one corner. A straightedge shall be placed along the panel so that the edges of the panel touch the straightedge. The dimensional characteristics of the panel shall not be disturbed. A rule graduated in fractional millimeters (inches) shall be used to measure the distance from the center of the panel face to the straightedge. Such distance shall be measured to the nearest 0.80 mm (1/32 in.) in all four directions.

990 The panel shall be freely suspended diagonally in an oven for 48 h at 82EC (180EF). After 48 h in the oven, the panels shall be removed and permitted to cool in free suspension at room temperature. Warpage measurements and corresponding direction shall again be recorded as described above.

j. Color. The panel shall be pigmented to a visually uniform gray color within the Munsel R range of N.7.5/ to N.8.5/.

(g) Samples and Tests.

1000 **1. Reflective Sheeting.** Each series and color of reflective sheeting will be tested, evaluated, and approved prior to use. A list of approved manufacturers' series and colors will be maintained by the Department. Only reflective sheeting series and colors from the List of Approved or Prequalified Materials in effect as of the date of letting shall be used in the contract. Manufacturers desiring evaluation of their reflective sheeting material shall contact the Evaluation Unit at the Procurement and Distribution Division to make arrangements to begin the evaluation process.

Reflective sheeting which is furnished under this specification shall be covered by a type C certification in accordance with 916.

1010 **2. Traffic Signal Materials.** Materials furnished under this specification with the exception of fiberglass reinforced plastic sign panels, shall be covered by a type C certification in accordance with 916. Fiberglass reinforced plastic sign panels shall be covered by a type B certification in accordance with 916.

913.11 Highway Illumination Materials. All luminaires, lamps, fuse kits, wire and cable, and major equipment shall be approved new material bearing the UL seal of approval or meet their standards.

Descriptive and technical literature shall be furnished for approval on all equipment prior to purchase and incorporation into the work.

1020 Warranties for all major equipment shall be in accordance with 807.02.

(a) Lighting Standards and Mast Arms, under 24. 4 m (80 ft) .

1. General Requirements. Conventional lighting standards shall be aluminum or steel and shall be in accordance with AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

1030 For conventional light standards, design wind velocity shall be 130 km/hr (80 mph). The maximum horizontal deflection of the pole under maximum loading conditions shall not exceed a deflection angle of one degree and 10 min from the vertical axis of the pole for any 0.3 m (1.0 ft) section of the pole along the entire length of the pole. The maximum stress shall be 80% of the AASHTO Standard Specifications for Group I DL loads. Vibration dampers shall be furnished as recommended by the manufacturer. The manufacturer may use drag coefficients based on actual wind tunnel tests; otherwise, he shall use the drag coefficients in Table 1.2.5c of Group I loads.

1040 Conventional light standards shall be designed to support a 24 kg (53 lb) luminaire with an effective projected area of 0.22 m² (2.4 ft²). When larger luminaires are specified the light standards shall be designed to support the larger luminaires and this shall be shown on the light standard shop drawings.

Conventional poles shall have a 100 by 200 mm (4 in. by 8 in.) reinforced hand-hole centered 460 mm (18 in.) above the base of the pole and a cover attached with a minimum of two stainless steel hex head bolts. The pole shall have a removable pole cap and a wire support hook to support the vertical drop of wire by a service drop clamp attached to the cable. A wiring hole with a 25 mm (1 in.) inside diameter grommet shall be provided where the arm is attached. Pole bases shall be designed for mounting on anchor bolts equally spaced on an 292 mm (11 1/2 in.) or 368 mm (14 1/2 in.) diameter anchor bolt circle. Anchor bolt covers shall be furnished.

1050

Hardware shall be type 304 or 305 stainless steel in accordance with ASTM A 276, except where otherwise specified.

For conventional poles, a 13 mm (1/2 in.) by 13 UNC threaded grounding nut or other approved method shall be provided near the bottom of and shall be accessible through the handhole for attaching the ground wire. The ground wire shall be No. 6 AWG soft-drawn, solid copper in accordance with ASTM B 3.

1060

Mast arms less than 2.4 m (8 ft) in length shall either be single member or truss type, except that mast arms on bridge deck light standards shall be truss type. Single member arms shall be a tapered tube oval shaped at the pole end with the long dimension in the vertical plane, welded to a pole plate and bolted or clamped to the shaft with a minimum of four 13 mm (1/2 in.) bolts. Mast arms 2.4 m (8 ft) and over in length shall be truss type. The upper member shall be a tapered tube oval shaped at the pole with the long dimension in the horizontal plane. The lower member may be standard pipe. Both members shall be welded to a pole plate and bolted or clamped to the pole. A minimum of four 13 mm (1/2 in.) bolts at the upper member and a minimum of two 10 mm (3/8 in.) bolts at the lower member shall be used if a pole plate configuration is used to attach the mast arm to the pole. Mast arms that are clamped to the pole shall have a minimum of four 13 mm (1/2 in.) bolts per clamp. Mast arms shall provide an enclosed raceway for the wiring and shall be free of burrs and rough edges. Each arm shall be furnished with a 50 mm (2 in.) nominal pipe size slipfitter. The maximum rise of the truss style arm shall be as set out in the table and shall be measured vertically from the centerline of the free end of the truss to a plane through the centerline of the upper arm bracket after loading.

1070

MAST ARM LENGTH m (ft)	MAXIMUM RISE m (ft)
27 or less (9)	1.2 (4)
3 to 4.3 (10 to 14)	1.5 (5)
4.5 to 5.8 (15 to 19)	1.7 (5.5)
6.1 to 7.6 (20 to 25)	1.8 (6)
7.9 to 9.1 (26 to 30)	2.4 (8)

1080

Light standards shall be constructed to provide a nominal luminaire mounting height above the roadway pavement as shown on the drawings. The elevations of foundations above or below the edge of the pavement shall be controlled by existing roadside conditions. The proper shaft length shall be determined by field measurement prior to placing an order for the poles.

A variation in the nominal mounting height of " 0.3 m (1 ft) is permitted so that the "Effective Mounting Height", foundation to luminaire, of the light standards may be supplied for 12.2 m (40 ft) nominal mounting height.

Elevation of Foundation Top with Respect to the Near Road Edge m (ft)	Effective Mounting Height, Foundation to Luminaire m (ft)
+ 2.13 to + 1.53 (7.00 to 5.01)	10.4 (34)
+ 1.52 to + 0.92 (5.00 to 3.01)	11.0 (36)
+ 0.91 to + .031 (3.00 to 1.01)	11.6 (38)
+ 0.30 to -0.30 (+ 1.00 to -1.00)	12.2 (40)
-0.31 to -0.91 (-1.01 to -3.0)	12.8 (42)
-0.92 to -1.52 (-3.01 to - 5.00)	13.4 (44)
-1.53 to -2.13 (-5.01 to -7.00)	14.0 (46)

1090 The effective mounting heights for other nominal mounting heights deviate from the table by the difference in the nominal heights.

2. Aluminum Lighting Standards.

1100 **a. Round Seamless.** The pole and mast arm shall be in accordance with ASTM B 241M (ASTM B 241), alloy 6063-T4, and of sufficient diameter and wall thickness to withstand the design loads. The pole shall be tapered full length or tapered in the middle with the top and/or bottom approximately 1/3 of the pole of constant cross section. The minimum wall thickness for poles on breakaway couplings and steel slip bases shall be 5.6 mm (0.219 in.). Poles on transformer bases or shoe anchor bases installed without breakaway devices are exempted from this minimum wall thickness requirement. An inner tube extension or sleeve fitted inside the main tube, shaft, is permissible to increase the wall thickness of the shaft starting at the bottom of the shoe base and extending upward towards the top of the pole. The sleeve or tube extension shall be no less than 0.9 m (3 ft) in length, fabricated from aluminum alloy 6063-T4 and heat treated to produce a T-6 temper after placing in the shaft. The minimum wall thickness of the combination of shaft and sleeve shall be 5.6 mm (0.219 in.). Attaching plates or clamps for aluminum mast arms shall be in accordance with ASTM B 241M (ASTM B 241), alloys 6061T6, 6063-T6, 356.0-T6, or 5052-H32. The bottom end of the shaft shall be welded to a one piece cast aluminum shoe anchor base of 356.0-T6 aluminum alloy in accordance with ASTM B 26M (ASTM B 26) for sand castings or ASTM B 108 for permanent mold castings or equal and provided with four slotted holes for anchor bolts and then the shaft's full length shall be heat treated to produce a T6 temper. The top of the shaft shall be provided with a removable aluminum pole cap. The shaft shall have no longitudinal welds. After fabrication, the shaft shall be cleaned to a satin finish and wrapped for protection during shipping and handling.

1110

1120 **b. Single Longitudinal Welded.** The material for these lighting standards shall be round, tapered structural marine aluminum sheet in accordance with ASTM B 209M (ASTM B 209), alloy 5086-H34, and of sufficient diameter and wall thickness to withstand the design loads. The minimum wall thickness for poles on breakaway couplings and steel slip bases shall be 5.6 mm (0.219 in.). Poles on transformer bases or shoe anchor bases installed with no breakaway devices are exempted from the minimum wall thickness requirement. The anchor base shall be one piece cast aluminum in accordance with ASTM B 26M (ASTM B 26), alloy 356.0-T-6. The base casting for the formed and welded shaft shall be designed to be inserted a minimum of 305 mm (12 in.) into the shaft and bonded to the shaft with a weatherproof structural epoxy adhesive that fully develops the required strength as specified by the design criteria. After fabrication, the shaft shall be cleaned to a satin finish and wrapped for protection during shipping and handling.

1140 **3. Stainless Steel Lighting Standards.** Stainless steel lighting standards shall be prefabricated from stainless steel in accordance with ASTM A 412, type 201, that has a minimum yield point of 469 MPa (68,000 psi). Welds other than spot welds shall be performed with conventional welding equipment and with stainless steel welding rods. Welds shall be free of cracks and pores. The wall thickness and diameter of the pole shall be sufficient to withstand designed loads. Exposed surfaces of the standard shall be smooth and free from marks or imperfections. During shipment, the poles and mast arms shall be protected with a non-staining protective material to preserve the finish.

1150 **4. Galvanized Steel Lighting Standards.** The pole and base plate shall be fabricated from steel in accordance with ASTM A 572M (ASTM A 572) or A 595 with a minimum yield of 345 MPa (50,000 psi). Single member mast arms and the upper members of truss type mast arms shall be fabricated from steel in accordance with ASTM A 572M (ASTM A 572 or A 595 with a minimum yield strength of 345 MPa (50,000 psi). The lower member of truss type arm may be fabricated from standard steel pipe in accordance with ASTM A 53 with a minimum yield strength of 250 MPa (36,000 psi). After fabrication, the pole and mast arm shall be thoroughly cleaned and galvanized in accordance with ASTM A 123.

Steel standards shall be tapered 11.67 mm/m (0.14 in./ft) and shall be round, octagonal, or dodecagonal. The design load shall be used to determine the pole diameter and wall thickness. The pole shall have one longitudinal electrically welded joint. A steel base plate shall be welded to each pole and provided with 4 slotted holes for the anchor bolts.

1160 All welds on steel standards shall be performed at the factory. Base plate welds shall be 100% penetration. Circumferential welds shall be backed-up welds with 100% penetration. Longitudinal welds shall be a minimum of 60% penetration. The 100% penetration welds shall be ultrasonically inspected and all other welds shall be inspected by magnetic particle. Welding shall be performed in accordance with 711.32.

5. Wood Pole Lighting Standards. Wood poles for highway lighting standards shall be in accordance with 913.15(e)2.

1170 **6. Frangible Breakaway Bases.** All light standards, except high mast towers, those protected by bridge end bents or retaining walls, shall be installed on breakaway devices. All breakaway devices on a contract shall be of the same type and manufacturer.

Breakaway devices shall be in accordance with AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals as modified in 913.11(a)1.

1180 A certification from the manufacturer shall be furnished with the shop drawings stating the breakaway devices conform to the breakaway criteria of the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.

a. Cast Aluminum Transformer Base. The anchor bolts for transformer bases shall be as accordance with 913.11(a)7. The anchor bolt circle for transformer bases shall be 381 mm (15 in.). The bolt holes in the transformer base may be slotted. The pole shall be bolted to the transformer base with four 25 mm (1 in.) diameter galvanized steel bolts.

An approved handhole in the transformer base may be substituted for the 100 mm by 200 mm (4 in. by 8 in.) handhole specified in 913.11(a)1.

1190 **b. Breakaway Coupling.** Breakaway couplings may be used with aluminum poles with mounting heights up to 15 m (50 ft) and with steel poles that weigh 272 kg (600 lbs) or less. The couplings shall be furnished with necessary hardware including a two piece cover. Couplings shall be installed in accordance with the manufacturer's instructions and recommended clearance between the top of the foundation and the bottom of the breakaway coupling.

1200 **7. Anchor Bolts.** Anchor bolts shall be 25 mm (1 in.) with 8NC rolled threads in accordance with ASTM A 307. The minimum length of threads shall be 150 mm (6 in.). Mean diameter of rod stock shall be 23.32 mm " 0.28 mm (0.918 in. " 0.011 in.) and out-of-round tolerance shall be " 0.3 mm (0.012 in.). The top 254 mm (10 in.) of the bolt shall be galvanized in accordance with ASTM A 153. Anchor bolts shall be in accordance with 910.19(b). The bolts shall be a minimum of 914 mm (36 in.) in length for poles 200 mm (8 in.) outside diameter or less and 1.22 m (48 in.) in length for poles 230 mm (9 in.) or 254 mm (10 in.) outside diameter. In addition to the minimum length, the bolt shall have a 100 mm (4 in.) right angle bend at the unthreaded end. The anchor bolts in bridge structures shall be as shown on the plans.

1210 **(b) High Mast Standards of 24.5 m (80 ft) and Over.** The high mast pole, base, anchor bolts, lowering device, installed fixtures, and associated appurtenances shall be designed to withstand a minimum wind speed of 155 km/h (90 mph), gust of 188 km/h (117 mph), using applicable design criteria in accordance with the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals. Minimum design criteria for each fixture shall be an effective projected area of 0.26 m² (2.8 ft²) and a weight of 38.6 kg (85 lbs). If larger fixtures are used the actual size and weight shall be used in the design of the pole.

1220 The Contractor shall be responsible for the accuracy of the dimensions and the proper fit of all material and equipment furnished with the pole. The Contractor shall provide all applicable manufacturer's warranties for material and workmanship. External lowering devices shall be designed to attach to the pole as shown on the plans. The pole shall include the mounting accommodations as shown on the plans.

1. High Mast Poles. The poles shall be made of steel in accordance with ASTM A 590, ASTM A 870, or ASTM A 560 grade C. The steel shall have a minimum yield strength of 410 MPa (59,500 psi).

1230 All steel used in the base plate and shaft shall meet an impact property of 20.3 J (15 ftAlbs) at + 4.5EC (+ 40EF) in the longitudinal direction using the Charpy V-Notch test. This shall be an average of 3 tests per mill heat with no test below 13.6 J (10 ftAlbs). A copy of the certified mill test reports for this steel and the Charpy V-Notch test results shall be submitted. Sufficient information shall be furnished to demonstrate that this material is traceable to the mill heat number shown on the test report.

 The tapered pole shall be multi-sided or circular in shape. The pole shaft sections shall be welded together or slipfitted. The minimum diameter of the pole top shall be 190 mm (7.5 in.) and shall provide at least 25 mm (1 in.) radial clearance from all interior devices.

1240 The exterior of the pole shall be thoroughly shotblasted or otherwise cleaned to a near white finish to remove all oily and foreign matter. The interior of the pole shall be cleaned of all mill scale and foreign matter by a pickling process or shotblasting.

 Hardware shall be stainless steel in accordance with ASTM A 276, type 304 or 305, except where otherwise specified.

1250 For the slipfit design, the pole shall be made up of not more than four sections for poles up to and including 36.6 m (120 ft) in length. For the poles between 36.6 m (120 ft) and 45.7 m (150 ft), five sections will be permitted. For poles over 45.7 m (150 ft) and up to 61 m (200 ft) six sections will be permitted. The inside edge of the lower section of the slip joint shall be beveled to prevent the transition joint assembly from catching on the edge. Slip-joints shall have a minimum overlap of 1 1/2 times the diameter of the bottom of the upper section. The sections shall be pre-fitted and matchmarked at the factory.

1260 **2. Welding.** All welds shall be performed at the factory. Circumferential welds shall be backed-up welds with 100% penetration. Longitudinal welds shall have a minimum of 60% penetration except within 0.6 m (2 ft) of either side of the circumferential joint, the welds shall be backed-up and of 100% penetration. Base plate welds shall be of 100% penetration. Circumferential welds and 100% penetration longitudinal welds shall be 100% ultrasonically inspected. The 60% penetration longitudinal welds shall be 100% ultrasonically or radiographically inspected for soundness. Welding shall be performed in accordance with 711.32.

1270 **3. Handholes.** Openings for handholes shall be reinforced to maintain the design strength of the pole. The handhole shall have a weatherproof gasket made of neoprene or silicone rubber. The gasket shall be formed for a forced fit around the handhole or be attached by mechanical means. Samples of the gaskets shall be furnished for approval. The door and hinges shall be the same type steel as the poles. The hinge pins and other securing hardware shall be stainless steel and tamperproof. The door shall be fabricated to allow for a padlock, which is not included in the hardware. The hasp used for padlocking shall be fabricated from stainless steel. Provisions shall be made to bolt the door securely shut. The door shall include a bugproof and weatherproof aperture with a minimum opening of 2580 mm⁵ (4 in⁵). Nylon or non-corrosive screens, or other approved methods of bugproofing shall be furnished. Two bonding plates shall be furnished which are accessible through the pole handhole for connecting the ground wires. A connection shall be furnished for an additional ground wire on the outside of the pole near the base plate.

1280 **4. Luminaire Ring Assembly.** The ring shall be fabricated from ASTM A 666 Type 201 or 304 stainless steel and shall have a removable raceway cover. The ring shall be designed as an enclosed wire raceway to provide for the symmetrical mounting of luminaires having an effective projected area of 0.26 m⁵ (2.8 ft⁵) and a weight of 38.5 kg (85 lbs) or actual projected area and weight, if greater. All structural connections shall be made with bolts and nuts.

1290 The luminaire ring shall be supported by three 5 mm (3/16 in.) stainless steel aircraft cables of seven strands with 19 wires each strand with a minimum breaking strength of 17,350 N (3900 lbs). The cables shall be secured to the ring, and to cable terminating devices within the poles by means of stainless steel hardware.

Positive positioning devices shall be incorporated into the ring assembly. These devices shall be designed to prevent any horizontal movement in the ring assembly. The ring assembly shall have a minimum of six nonabrasive rollers mounted on the ring interior.

1300 **5. Head Frame Assembly.** The head frame shall be made of ASTM A 666 Type 201 or 304 stainless steel. All required pulleys, rollers, or sheaves and shafts shall be constructed from non-corrosive metallic materials. No component shall be used in the lowering device in excess of its rating or in violation of the component manufacturer's recommendation. This requirement shall be applicable, but not limited to, the compatibility of the cables and sheaves. There shall be three supports for the suspension cables. A roller system or one compatible sheave for the power cable shall be located mid-point between two of the suspension supports. To prevent the cables from riding out of the grooves, cable guides shall be provided. The suspension cable sheaves shall have a minimum pitch diameter of 90 mm (3.5 in.) and the power cable sheave or individual rollers in a roller assembly shall have a minimum pitch diameter of 470 mm (18.5 in.) and shall be grooved to fit the power cable.

1310 All components at the top of the pole shall be protected from the weather by a dome fabricated from steel in accordance with 913.11(b)1, fiberglass, or spun aluminum.

1320 The dome shall be secured to the head frame assembly with at least eight fasteners around the perimeter of the dome. The dome shall be reinforced at the points of attachment and it shall be fitted to the head frame assembly so that no visible distortion occurs to the dome when it is properly installed. The dome attachment shall be designed to withstand pole vibration, other pole movement, and the design windload. The fiberglass dome shall be made of material that is not subject to cracking or other deterioration because of aging.

1330 **6. Winch Assembly.** The winch cable shall be 8 mm (5/16 in.) diameter galvanized steel aircraft cable of 7 strands with 19 wires each strand with a minimum breaking strength of 9800 pounds 43,600 N (9800 lbs).

1330 The winch shall have a drum with a minimum diameter of 100 mm (4 in.) and drum flanges with a minimum diameter of 200 mm (8 in.). The drum shall be supported at each end by a rigidly mounted permanently lubricated bearing capable of carrying the design load. The winch drum shall be designed to allow the cable to lay in even consecutive layers.

1330 The winch shall be driven by a self locking, worm gear reducer. The gear reducer shall be permanently lubricated and totally enclosed in a cast aluminum or cast iron housing. The winch assembly shall be powered by an external drive system.

7. External Drive System. The external drive system shall be powered by a heavy duty reversing NEMA frame motor with an electromagnetic friction breaking mechanism rated at a minimum of 8.15 J (6 ftAlbs.) of torque per motor 745.7 W (hp). The brake shall be actuated each time the power to the motor is interrupted. The breaking mechanism shall be an integral part of the motor housing. The motor operated drive shall have a factory set torque limiter or clutch. This clutch assembly shall be calibrated to position the ring at the top of the pole and not exceed 80% of yield strength of the cable.

The external drive system shall operate with the 240/480 AC volt power available at the pole or incorporate a transformer into the system. The external drive system may use either the luminaire power plug or a separate outlet with a 600 volt, 30 ampere rating. The external drive system shall be operable from a minimum distance of 7.6 m (25 ft) from the pole. The control voltage for any hand-held control equipment shall not exceed 120 volts. The hand-held control equipment shall be shock proof.

The external drive system shall be capable of operating all high mast pole installations. Shop drawings shall be furnished in accordance with 913.11(g) and shall include the dimensions and the wiring diagram of the standard connections of the external drive system. The external drive system shall be mounted on a two wheel cart with wheels at least 300 mm (12 in.) in diameter and the weight shall be distributed so that it presents a balanced load.

8. Cable Terminator. The three luminaire ring support cables shall be attached to three stainless steel helical compression springs incorporated into the cable terminating device. These springs shall be designed to compensate for inequalities in the cable lengths and to maintain adequate tension on the support cables through pole and cable thermal expansion and contraction.

The cable terminator shall incorporate a separate eye bolt on the bottom of the device for the attachment of a cable or chain to hold the luminaire ring in a raised position while the winch cable or winch assembly is being inspected or repaired. The cable terminating device shall be designed to prevent the device from catching on the slip joint of the structure.

9. Lightning Rod Assembly and Grounding System. The lightning rod, air terminal, shall shield the head frame assembly cover and the outer edge of the luminaires within a 45 degree electrostatic shielded cone. The grounding system shall include bonding plates, grounding clamps, four 16 mm (5/8 in.) diameter by 3.7 m (12 ft) copperweld grounding rods, a grounding conductor with a minimum size of 28 strands of 14 gauge bare copper wire in rope lay configuration, 14 mm (9/16 in.) diameter with a weight of copper of 136 kg (375 lbs) per 306 m (1000 ft), air terminal, lightning rod and other incidental connectors. All hardware shall be stainless steel, brass, copper, copper alloy, or equally corrosion-resistant metal.

Bonding plates, with a minimum contact surface area of 5160 mm² (8 in²), shall be installed at locations shown on the plans. The bonding plates shall be welded to the tower shaft during the time of manufacturing. The grounding conductor shall be secured to the bonding plates by a two bolt pressure plate clamp connector having a minimum of 100 mm (4 in.) of contact with the copper wire. At the point of termination the grounding conductor shall extend beyond the bonding plate a minimum of 75 mm (3 in.).

1390 Each ground rod clamp shall have a minimum of 38 mm (1 1/2 in.) of contact between the grounding conductor and the ground rod. The grounding conductor shall be continuous between the bonding plates inside the tower shaft handhole and the grounding rod termination point.

Bends of conductors shall form an angle of 90 degrees or more. Unsupported conductors shall have a radius of bend 200 mm (8 in.) or greater.

1400 **10. Anchor Bolts.** Anchor bolts for high mast poles shall be furnished in a pre-clustered form and shall be a hooked deformed reinforcing bar or a hooked smooth bar. The bolts shall be in accordance with ASTM A 615M (ASTM A 615) modified to a minimum yield strength of 517 MPa (75,000 lbs). The top 300 mm (12 in.) of each anchor bolt, nut, and washer shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

(c) Wire and Cable. Lighting circuit cables for direct burial shall be enclosed in polyethylene conduit.

1410 **1. Polyethylene Conduit.** This conduit shall be in accordance with ASTM D 3485 either medium density type II, class C or high density type III, class C smooth wall, coilable polyethylene conduit for preassembled wire and cable.

The size of the conduit for different cable conductor sizes shall be as follows:

Cable Conductor Size	Conduit Size
3-1/C No. 4	32 mm (1 1/4 in)
3-1/C No. 2	38 mm (1 1/2 in.)
3-1/C No. 1/0	50 mm (2 in.)
3-1/C No. 3/0	50 mm (2 in.)

1420 **2. Conductors in Cable-Duct.** The cable shall consist of three separate electrically insulated conductors installed in the duct so any one conductor may be easily removed without damage to the other two. The conductors shall not be cabled or twisted together. The conductors shall be stranded copper of the AWG size specified. Conductor sizes No. 8 AWG and larger shall be stranded in accordance with ASTM B 8, class B.

Each conductor shall be insulated with crosslinked polyethylene manufactured in accordance with Insulated Power Cable Engineer Association publication S66-524. Each conductor shall have the following characteristics: a 600 volt rating; UL listed; an XHHW conductor temperature rating not to exceed 90EC in dry locations; and not to exceed 75EC in wet locations.

1430 Each of the three conductors shall be imprinted at regular intervals with the following description: Type XHHW; 600 volt; UL; the conductors' AWG size and metal or alloy; the manufacturer's name, trademark, or other distinctive marking by which the product can be readily identified.

Identification coding of the conductors shall be accomplished by complete color coding or by ribbing of the insulation. Color coding of the insulation shall be homogeneous throughout the entire depth and length of the jacket. The colors shall include one black, one white, and one red. Ribbing shall consist of one non-ribbed conductor, one single ribbed conductor, and one double ribbed conductor. The same method of conductor identification coding shall be used throughout the project.

1440 **3. Lighting Standard Circuit Wiring.** This wiring shall consist of two 1/C No. 10 AWG, 600 volt, THWH or MTW insulation, stranded, copper wire.

1450 **4. Sign and Underpass Wiring.** The wiring from the switch box to the last luminaire shall be 3/C copper stranded No. 10 AWG conductors and shall have imprinted at regular intervals along the length of the insulation jacket the following designation: No. 10 AWG, type MTW or THHN or THWN or Gasoline and Oil Resistant II or AWM, 600 volt, UL. The conductor classifications shall be UL listed and have the following minimum temperature ratings: MTW 90EC; THHN 90EC; THWN 75EC; and AWM 105EC. It shall be installed in 19 mm (3/4 in.) conduit between the breaker box and luminaires.

5. Aerial Cable. This cable shall be triplex secondary distribution cable consisting of two insulated conductors and a steel reinforced bare copper messenger neutral. The insulated conductor shall be No. 6 AWG stranded copper with 600 volt, XHHW-XLP type insulation.

1460 **6. High Mast Tower Luminaire Ring Conductors.** The wiring from the terminal box on the ring through the last luminaire shall be in accordance with 913.11(c)4.

7. Power Cable-High Mast Poles. The power cable shall be a 4/C No. 10 AWG copper insulated electrical cable type "SO" modified for a repetitive reeling operation. It shall be in accordance with ASTM B 3, ASTM B 173, and IPCEA S-19-83. Conductor insulation shall be in accordance with ASTM D 169 and IPCEA S-19-81, Paragraph 3.12. The sheath or jacket shall meet or exceed IPCEA S-19-81, Paragraph 7.6.20.1.1. Conductors shall be color coded.

1470 The power cable shall have a heavy-duty 600 volt, AC 30 amp rated electrical plug capable of disconnection in a safe manner under load conditions. The electrical plug shall be moisture resistant and waterproof at both transition points.

8. Electrical Connectors. Connectors shall be a compression type of the proper size with only one conductor per groove in the fitting. They shall be designed specifically for use on aluminum and copper conductors, prefilled with an oxide inhibitor and installed with a hydraulic tool according to the manufacturer's specifications. After installation, the connectors shall be fully insulated and weatherproofed. The connectors installed in underground handhole shall be taped and then waterproofed as shown on the plans.

1480 **(d) Luminaires.**

1. General Requirements. Lamps supplied for luminaires shall be electrically compatible with the luminaires. Luminaires shall include the lamp ballast. The ballast shall be integrally built in and of the constant wattage regulator type of sufficient size to operate the designated lamp at the required voltage. The ballast shall provide satisfactory lamp performance to -7EC (20EF) with an input voltage variation of "10% of the rated operating voltage specified.

1490 Luminaires shall include vandal shields when installed on an underpass or signs on bridge brackets and when otherwise specified. The vandal shield shall be made of a tough durable plastic, such as Lexan, mounted in a rugged galvanized steel or aluminum frame, and shall withstand severe impact without being damaged or allowing the refractor to be damaged. It shall be fastened securely to the luminaire so it can not be removed from the outside and shall not interfere with the light distribution pattern. It shall protect the face of the refractor and if ventilation is necessary, the ventilating apertures shall be arranged so that they do not admit a probe of a diameter greater than 6 mm (1/4 in.).

1500 **2. Roadway Lighting Luminaires.** Roadway lighting luminaires shall have a precision-cast aluminum housing and refractor holder with weatherproof finish. They shall have a strong, easily operated, positive latch on the street side of the refractor holder and a hinge with a safety catch that prevents accidental unhinging on the house side of the refractor holder. They shall include a slipfitter capable of adapting to a 50 mm (2 in.) mounting bracket; an easily detachable highly specular aluminum reflector; and an easily adjustable socket in both horizontal and vertical directions capable of producing lighting patterns to meet all the requirements of the American Standard Practice for Roadway Lighting as sponsored by the Illumination Engineering Society and as shown on the plans. They shall have a high impact, heat-resistant, glass, prismatic refractor; and include gasketing that will completely seal out dust, moisture, 1510 and insects from the interior of the optical assembly and retard the formation of an undesirable film from gaseous vapors on the interior of the optical assembly.

3. Sign Luminaires. Luminaires shall be 250W mercury vapor unless otherwise specified. Sign luminaires shall have the same requirements as roadway luminaires plus a shield that blocks the view of the refractor from an approaching motorist. This shall be accomplished by the design of the housing or by a shield fabricated from sheet aluminum, approximately 1.3 mm (0.05 in.) thick, and of sufficient size to be fastened onto the horizontal edge of the refractor holder with self tapping screws and placed between the refractor and approaching traffic.

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Aluminum and steel structural members for luminaire supports shall include aluminum conduit, conduit clamps, fittings, and stainless steel screws.

4. Underpass Luminaires. Underpass luminaires shall have the same requirements as roadway luminaires except they shall have vandal shields and the ballast shall meet the same requirements except it may be mounted separately near the luminaire as shown on the plans.

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5. High Mast Luminaires. The luminaires shall be in accordance with the American Standard Practice for Roadway Lighting by the Illumination Engineering Society and shall produce lighting patterns as shown on the plans. The lamp in the high mast luminaire shall be supported at both ends with mechanical spring grips or other means to hold the lamp secure against vibration. The socket shall be mogul sized and porcelain enclosed. The luminaire housing shall be an enclosed aluminum unit with a reflector and borsilicate glass refractor. It shall include gasketing that completely seal out dust, moisture, and insects from the interior of the optical assembly and retard the formation of an undesirable film from gaseous vapors on the optical assembly.

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(e) Circuit Breakers and Enclosure. All circuit breaker enclosures shall be NEMA 4/5.

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1. Circuit Breakers for Type II Service Point. The cabinet and hardware shall be weatherproof and rain tight. The enclosure shall have provisions for pad locking. The fastener and mounting hardware shall be plated brass, stainless steel, or aluminum. The enclosure shall be made of 14 gauge aluminum or 1.5 mm (14 or 16 gage) stainless steel. The circuit breaker operating handles for manual tripping shall be concealed inside the enclosure. Computation of branch circuits shall be based on the National Electrical Code Standard Limitation of loading breakers to 80% of their rated current. Additional details shall be as shown on the plans.

2. Circuit Breakers for Sign and Underpass Circuits. Sign and underpass circuit protection shall be provided by two single pole, 240 volt AC, 120 volt for 120/240 volt service, circuit breakers with ampere rating of 200% of the normal load. The circuit breakers shall have provisions for padlocking externally. The circuit breaker operating handles for manual tripping shall be concealed inside the enclosure. The enclosure shall be made of aluminum or stainless steel. Additional details shall be as shown on the plans.

1560 **3. Circuit Breakers for High Mast Poles.** The enclosure shall be furnished with two single pole, 30 ampere, 480 volt AC circuit breakers with a minimum symmetrical RMS interrupting capacity of 14,000 amperes. The breakers shall be accessible through the pole handhole. The circuit breaker operating handles for manual tripping shall be external to the enclosure. The enclosure shall be made of aluminum or stainless steel. Additional details shall be as shown on the plans.

4. E-Series Magnetic Circuit Breakers. These breakers shall have the following features:

- 1570 a. capable of 10,000 on-off operations;
- b. interrupting capacity of 7,500 amperes;
- c. temperature stable so as not to be adversely affected by temperature changes over their operating environment of -40EC (-40EF) to 85EC (185EF);
- d. lug range 1/0 - 14 copper and 1/0 - 12 aluminum; and
- 1580 e. trip on overload, even when handle is forcibly held in the ON position.

(f) Multiple Relay Switches with Photocell Receptacles. Multiple relay switches with photocell receptacles shall have a two pole relay for connection to a 120/240 or 240/480 volt, 3 wire, single phase, 60 hz power supply. The relay switch components shall match the service voltage being supplied. The unit shall contain two single pole circuit breakers with a minimum rated capacity to withstand 100% of the rated ampere load. The circuit breakers shall trip at not less than 125% of the rated load capacity. Control circuit arresters for lightning protection and a manual control selector switch shall be included within the unit. The enclosure shall be a cast aluminum weatherproof case, with a hinged cover, having provisions for padlocking and a hanger for pole or wall mounting.

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(g) Shop Drawings. Six sets of shop drawings shall be submitted for lighting standard assemblies, luminaires, service points, circuit breaker enclosures, external drive assemblies, and multiple relay switches. A copy of the transmittal shall be given to the Engineer. These items shall not be ordered or installed until shop drawings have been approved.

1600 These drawings will be reviewed for design features only. The Contractor shall be responsible for dimensions, accuracy, and fit of work. The drawings for conventional light standards shall show the shaft outside diameter, height, wall thickness, the arm length rise, size, handhole details, grinding details, materials used, and complete anchor bolt details including bolt circle-projection and hardware. When a breakaway base is required, details shall be shown. Service point shop drawings shall show the arrangement and brand name of each component.

1610 When requested, sufficient design data shall be furnished with the drawings to verify the conventional light standards meet wind load, deflection, vibration, and breakaway requirements. All of the above shall be based upon the lighting standards as shown on the plans. After approval, the Engineer shall be advised of where changes to the Installation Summary Sheets must be made because of existing roadside conditions. Where necessary, additional light standard drawings shall be submitted for approval.

Unless calculations are on file with the Department, the following design calculations and data shall be submitted for approval prior to the fabrication of any parts of the high mast pole.

1. general dimensions of all component parts;
- 1620 2. the maximum moments, the section modulus required, and the section modulus furnished at the base of the pole, at all splices, at the connection of the ring and at least every 6.1 m (20 ft);
3. computation of stresses in base plate, connection attachment, and anchor bolts;
4. maximum deflection at the top of the structure under the specified loading; and
- 1630 5. the dimensions and wiring diagrams of the external drive system connection to the pole in accordance with in 912.11(b)7.

(h) Materials Certification. Unless otherwise specified, materials furnished under this specification require a type C certification in accordance with 916.

913.12 Construction Warning Lights. Construction warning lights shall be self-illuminated by means of an electric lamp behind the lens. Types A and C shall also be externally illuminated by reflex-reflective elements built into the lens to enable it to be seen by the light from the headlights of oncoming traffic.

1640 The batteries shall be entirely enclosed in a case. The case shall be secured by a locking device which can be opened with a special tool.

(a) Flash Requirements.

1. Flash Rate. The light from types A and B shall have a flash rate of 65 " 10 pulsations per minute from -29EC (-20EF) to + 66EC (150EF).

1650 **2. On-Time.** On-time is defined as the period of the flash when instantaneous intensity is equal to or greater than the effective intensity as specified in 913.12(b)1.

a. Type A. The light shall have an on-time of no less than 10% of the flash cycle.

b. Type B. The light shall have an on-time of no less than 8% of the flash cycle.

(b) Optical Requirements.

1660

1. Effective Intensity. The light beam projected upon a surface perpendicular to the axis of the light beam shall produce a lighted area within the solid angle bounded by the two vertical planes nine degrees from the vertical plane through the axis of the optical system and two planes five degrees above and below the horizontal plane through the optical axis of the system.

For type A, the effective intensity shall not drop below 4.0 cd (4.0 candles) within the area specified herein during the first 336 h of continuous flashing.

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For type B, the effective intensity shall not drop below 35 cd (35 candles) within the area specified herein during the first 168 h of continuous flashing.

For type C, the effective intensity shall not drop below 2.0 cd (2.0 candles) within the area specified herein during the first 168 h of continuous burning.

2. Lens Illumination. The illuminated lens shall be uniformly bright in appearance over its entire illuminated surface when viewed from any point within the angle defined in 913.12(b).

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3. Reflex-Reflective Performance. For types A and C the specific intensity of the lens when acting as a reflex-reflector at an observation angle of 0.2 of a degree shall be no less than the following:

Entrance Angle (degrees)	Specific Intensity Candelas per lux (Candles per Footcandle)
0	1.67 (18)
10	1.40 (14)
20	0.65 (7)

4. Testing Procedure. The effective intensity of types A and B lights shall be calculated using the Guide for Calculating the Effective Intensity of flashing Signal Lights as approved by the Illuminating Engineering Society, June, 1961. The intensity of the type C light shall be tested in accordance with SAE Standard J 575d, Lighting Equipment and Photometric Tests. Reflex-reflection shall be tested in accordance with SAE Standard J 594d.

(c) Lens Requirements.

1. Size of Lens. The lens shall be no less than 175 mm (7 in.) in diameter including for a reflex-reflector ring of 13 mm (1/2 in.) minimum width around the periphery for types A and C.

2. Directional Lenses. Unless otherwise directed, types A, B, and C shall have uni-directional lenses.

3. Lens Chromaticity. If the light uses an incandescent lamp, the chromaticity of the lens color shall be defined by the tri-stimulus coordinates of the Commission International d'Eclairage Standards. When tested with illuminants from 2856 K to 2366 K, the lens color shall fall within the area of the chromaticity diagram in accordance with the 1931 Commission International d'Eclairage Standard Observer as defined by the following coordinates:

X	Y	Z
0.543	0.452	0.005
0.548	0.452	0.000
0.584	0.411	0.005
0.589	0.411	0.000

If the light uses other than an incandescent lamp, the light output shall be in the same range as the light obtained with the incandescent lamp and the specific lens.

4. Lens Luminous Transmittance. The minimum relative luminous transmittance of the lens with illuminant at 2856 K shall be 0.440.

5. Lens Material. The lens shall be plastic of one piece construction and shall meet the test requirements in accordance with SAE J 576b, except that the exposure time and condition, paragraph 3.4.3, for the purposes of this standard shall be one year.

(d) Head and Case.

1. Swivel Head. If swivel capabilities as described herein are not incorporated in the device used to mount a type A or C light on a barricade or sign, the head shall be mounted on the housing in a manner permitting it to be swiveled through a minimum 90 degrees arc in a horizontal plane. If swiveling is accomplished by rotation of the head, construction shall be such that the head rotation shall not damage the wiring.

1730 **2. Case.** The case shall be so constructed and closed as to exclude moisture that would affect the specified operation of the light. The case shall have a weephole to allow the escape of moisture from condensation.

(e) Photoelectric Controls. Photoelectric controls, if provided on types A or C lights, shall keep the light operating whenever the ambient light falls below 215 lux (20 footcandles).

1740 **913.13 Flashing Arrow Sign.** The flashing arrow sign shall be an all weather, self-contained flashing sign designed to display the required flashing messages continuously for a minimum of 24 h, without servicing. A reserve storage battery shall be provided to automatically operate the flashing arrow sign for a minimum period of 8 h if there is a power failure of the primary source.

1750 The flashing arrow sign shall have a control unit which incorporates a photo-controlled transfer relay for automatic lamp intensity settings. The highest photo-controlled setting shall be full intensity for daylight operation. The lowest photo-control setting shall be for night-time operation and shall be 50% of full intensity when the ambient light level drops below 54 lux (5 footcandles). A minimum of two interim photocontrolled settings shall automatically increase or decrease the lamp intensity in direct proportion to the ambient light level.

The flashing arrow sign shall have a manual control unit for adjusting lamp intensity when automatic operation becomes unsatisfactory. The manual control shall be fully adjustable between the minimum limit of 30% of full lamp voltage and maximum limit of full lamp voltage.

An indicator light shall be provided on the back of the sign to provide confirmation that the flashing arrow sign is operating. The indicator light shall be visible for 150 m (500 ft).

1760 **(a) Solar Powered.** Solar power assisted units shall incorporate a target sight device and leveling mechanism to aid the user for positioning of the unit prior to use. The device shall be attached to the elevated portion of the flashing arrow sign and not to the fixed support frame.

1770 The lamps shall be electronically operated by means of a solid state controller. An automatic lamp intensity regulator shall hold the lamp output constant with varying battery voltage. The control system shall incorporate a full time tracking system designed to track ambient light for 24 h a day. The control system shall adjust lamp intensity to provide maximum system efficiency. The controller shall be in a weatherproof, ventilated, lockable enclosure.

The lamps shall provide amber beams with a minimum of a 20E horizontal and 6E vertical field of view. The minimum effective luminance within the required beam shall not be less than one half the effective luminance at the beam center.

1780 The battery bank shall consist of 12 v, deep cycle, batteries. The battery bank shall be of sufficient capacity to power the unit for 15 days with no assistance from the sun. A battery condition indicator and a test switch shall be provided to monitor the system's battery charge. The batteries shall be secured in a well-ventilated, weatherproof lockable housing. A low battery charge indicator which shall be visible to maintenance personnel driving past the sign shall be provided to indicate the need to recharge the batteries. The battery bank shall be at full charge when delivered to the project site.

The unit shall be equipped with a sign/solar panel lifting mechanism. The lifting mechanism shall be designed to safely carry the capacity of the sign's load. The lifting mechanism shall incorporate a positive locking device to secure the panel in a raised or lowered position.

1790 Solar power assisted flashing arrow signs to be used shall be selected from the Department's list of Approved Solar Power Traffic Control Devices.

(b) Diesel Powered. Flashing arrow sign shall be fueled by diesel fuel only.

(c) AC Powered. When connected to an AC electrical power source, provisions shall be made to prevent electrocution.

FLASHING ARROW SIGN GENERAL SPECIFICATIONS

	TYPE A	TYPE B	TYPE C	SOLAR POWER ASSISTED
Minimum Board Size	0.6 m (2 ft) high x 1.2 m (4 ft) wide**	See Note Below	1.2 m (4 ft) high x 2.4 m (8 ft) wide	1.2 m (4 ft) high x 2.4 m (8 ft) wide
Minimum No. of Lamps Flashing Arrow Flashing Double Arrow Sequential Chevron (3 Heads Minimum)	5 in head, 5 in shaft* 5 in head, 4 in shaft* 5 in head		Same as Type A	5 in head, 5 in shaft* 5 in head, 3 in shaft* 7 in shaft
Lamp Type	Sealed Beam - 12.8 V, not to exceed 3 A Ave. rated life - 300 h. Min. Candlepower - 1000 cd (1000 candles) Min. 9700 cd (9700 candles) Max.		Same as Type A	Sealed beam - 12.8 V, not to exceed 3 A Average rated life - 300 h Min. Candlepower - 600 cd (600 candles) at normal voltage and \$ 250 cd (250 candles) at low voltage
Lens Color	Amber		Amber	Amber
Board Color	Flat Black		Flat Black	Flat Black
Flashing Rate	30-50 F.P.M. (50% on time)		30-50 F.P.M. (50 % on time)	25-40 F.P.M. (50% on time)
Message (Left or Right)	Flashing Arrow, Flashing Double Arrow, or Sequential Chevron		Flashing Arrow, Flashing Double Arrow	Flashing Arrow, Flashing Double Arrow, or Warning Bar
Minimum mounting height (to bottom of board)	2.1 m (7 ft)		2.1 m (7 ft)	2.1 m (7 ft)
Where Permitted	Where normal speed limit is less than 40 mph		All rural & urban locations	Stationary Operations Tangent Sections (See 801.13(a))
Required Minimum Visibility	0.8 km (0.5 mi)		1.6 km (1 mi)	1.6 km (1 mi)

* When flashing a single or double arrow(s), the lamp(s) nearest the arrow points shall not be illuminated.

** Either rectangular or arrow shaped black background sign will be permitted.

Note: General specifications for a type B flashing arrow sign are shown in the Federal MUTCD.

1800

913.13.1 Temporary Worksite Speed Limit Sign Assembly. The temporary worksite speed limit sign assembly shall be an all-weather, self-contained unit designed to display speed limit signs in accordance with the MUTCD and as shown on the plans. The signs shall be installed on frangible posts or mounted on movable stands or trailers in accordance with 910.14(f). The power source shall be capable of operating the strobe lights, without service, for the period which the sign is in effect. An on/off switch will be required.

1810

913.14 Pavement Marking Material.

(a) Traffic Paint. Traffic paint shall be in accordance with 909.05.

(b) Durable Marking Material. Durable marking material shall be thermoplastic, preformed plastic, or 100% solids epoxy.

1. Thermoplastic. This material shall be supplied in the solid form and heated to achieve a plastic state suitable for application. In the plastic state, the material shall not give off fumes which are toxic or otherwise injurious to persons or property. The material shall not breakdown, deteriorate, scorch or discolor if held at the application temperature of 204EC (400EF) to 232EC (450EF) for a period of 4 h or by reason of reheating to the application temperature four additional times. The temperature versus viscosity characteristics of the material shall remain constant through the four reheatings and shall be constant from batch to batch. The color shall be stable through the four reheatings and shall be the same from batch to batch.

1820

The thermoplastic material shall be homogeneous and free from dirt, foreign objects, or ingredients which will cause bleeding, staining or discoloration. The thermoplastic material shall not be adversely affected by contact with deicing chemicals, bituminous paving materials, or drippings from vehicles.

1830

The marking shall have a uniform cross section. Pigment shall be evenly dispersed throughout the material. The density and character of the material shall be uniform throughout its thickness. The marking shall maintain its original dimensions and placement.

The thermoplastic material shall remain intact under normal traffic conditions at temperatures below 49E C (120E F). The material shall not separate from the pavement in freezing weather. Cold ductility of the material shall be such as to permit normal movement with the road surface without chipping or cracking.

1840

The color of the white plastic film shall be determined by a standard color difference meter, such as the Gardner Color Difference Meter manufactured by Gardner Laboratories, Inc., Bethesda, Maryland. The plastic film shall not show deviations from a magnesium oxide standard greater than the following:

SCALE	DEFINITION	MAGNESIUM OXIDE	SAMPLE
Rd	Reflectance	200	70 Minimum
a	Redness-Greenness	0	-5 to + 5
b	Yellowness-Blueness	0	-10 to + 10

1850 The color of the yellow plastic film shall visually match color No. 33538 of Federal Standard 595a. The pigment shall include medium chrome yellow.

a. Material Requirements. The filler to be incorporated with the resins shall be white calcium carbonate meeting requirements of ASTM D 1199, type GC, grade II or III. The binder shall consist of a mixture of non-drying synthetic resins at least one of which is solid at room temperature. The total binder content of the thermoplastic compound shall be from 18% minimum to 35% maximum by weight. The white thermoplastic shall have a pigment containing a minimum 10% titanium dioxide. The glass beads shall be in accordance with 912.09.

1860 **(1) Reflectorization.** During manufacture, reflectorizing beads shall be mixed into the compound from 20% minimum to 35% maximum by weight of the material.

(2) Set Time. The set time to bear traffic shall have a lower limit of 2 min maximum at 10EC (50EF) surface temperature and an upper limit of 15 min at 32EC (90EF) surface temperature when the film is applied at the maximum permitted thickness.

1870 **(3) Water Absorption.** The retained water shall not exceed 0.5% by weight when tested in accordance with ASTM D 570, procedure A.

(4) Softening Point. Material shall have a softening point of 88EC (190EF) minimum when tested in accordance with ASTM E 28.

(5) Specific Gravity. Specific gravity of the compound at 25EC (77EF) shall be from 1.9 to 2.5.

1880 **(6) Impact Resistance.** The impact resistance shall be a 1.7 J (15 inAlbs) minimum at 25EC (77EF) after the material has been heated for 4 h at 204.5EC (400EF). The material shall be cast into bars of 25 mm (1 in.) cross sectional area and 75 mm (3 in.) long and placed with 25 mm (1 in.) extending above the vise as a cantilever beam, Izod type tester using the 2.8 J (25 inAlbs) scale in accordance with ASTM D 256.

(7) Low Temperature Stress Resistance. Samples shall not crack nor fail to adhere to substrate when tested. A line sample which is a minimum of 0.021 m²(32 in²) in area shall be applied to an asphalt paving block in a manner equivalent to an actual road installation. The block shall be immersed in cold water for 1 h, then immediately placed in a freezer chest or other insulated cold compartment maintained at -7EC (20EF) for 24 h. The block shall be removed from the cold compartment and allowed to come to normal room temperature. The line sample shall show no cracking or flaking off the block when examined following the exposure cycle.

(8) Bond Strength. Two concrete blocks 50 mm by 90 mm by 178 mm (2 in. by 3 in. by 7 in.) shall be bonded together on the 76 mm by 178 mm (3 in. by 7 in.) faces with a 1.6 mm (1/16 in.) to 3.2 mm (1/8 in.) layer of the thermoplastic marking material and tested in accordance with ASTM C 321, the bond strength shall not be less than 150 pounds per square inch (1.034 MPa).

(9) Hardness. The material shall be conditioned by heating for 4 h at 204EC (400EF). The hardness shall be measured at the designated temperatures as the material cools and shall comply with the indicated minimum reading. The hardness shall be measured after 15 s of penetration using the Shore Durometer type A in accordance with ASTM D 2240.

TEMPERATURE	READING
46EC (115EF)	65
25EC (77EF)	95
2.5EC (40EF)	95

b. Packaging. The thermoplastic material shall be delivered in unit containers. Each unit container shall be clearly marked to indicate the color of the material, the process batch number or similar manufacturer's identification, the manufacturer's name and location of plant, and the date of manufacture.

c. Basis for Use. A type C certification in accordance with 916 shall be furnished for the thermoplastic material.

2. Preformed Plastic. This material shall consist of a homogeneous preformed plastic film with a minimum thickness of 1.5 mm (60 mils) and a width as specified. The preformed plastic material shall have a precoated adhesive and an easily removable backing which shall protect the adhesive in storage and facilitate rapid application. The adhesive shall allow the preformed plastic material to be repositioned on the pavement surface to which it is applied before permanently fixing it in its final position with downward pressure.

The plastic material shall be capable of being affixed to either bituminous concrete pavement or cement concrete pavement by means of the precoated adhesive and, following the initial application of pressure, shall mold itself to pavement contours, breaks, and faults by traffic action at normal pavement temperatures.

1930 The color of the white plastic film shall be determined by a standard color difference meter, such as the Gardner Color Difference Meter manufactured by Gardner Laboratories, Inc., Bethesda, Maryland. The plastic film shall not show deviations from a magnesium oxide standard greater than the following:

SCALES	DEFINITION	MAGNESIUM OXIDE	SAMPLE
Rd	Reflectance	100	70 Minimum
a	Redness-Greenness	0	-5 to + 5
b	Yellowness-Blueness	0	-10 to + 10

The color of the yellow plastic film shall be visually match color No. 33538 of Federal Standard 595a. The pigment shall include medium chrome yellow.

1940 **a. Material Requirements.** The material shall be composed of plasticizers, pigments and glass beads. The pigment shall contain 20% minimum titanium dioxide for white plastic material. During manufacture, glass beads shall be mixed into the compound at a minimum of 15% and a maximum of 20% by weight. A layer of glass beads shall be bonded to the top surface.

1950 **(1) Tensile Strength.** The specimens for this test shall be Type I prepared in accordance with ASTM D 638M (ASTM D 638). A sample 150 mm by 25 mm (6 in. by 1 in.) shall be tested at a temperature between 21EC (70EF) and 27EC (80EC) using a jaw speed of 6.4 mm (0.25 in.) per minute. 25 mm (1 in.) squares of carborundum extra coarse emery cloth or equivalent may be applied to each end of the test sample to prevent the plastic adhesive from adhering to the test equipment. The break resistance shall be based on an average of at least three samples. The elongation of the film at rupture shall be 15% minimum and 50% maximum. The minimum tensile strength shall be 275.8 MPa 40 psi).

1960 **(2) Adhesive Stability Test.** A 75 mm by 150 mm (3 in. by 6 in.) sample of plastic material shall be applied to a 75 mm by 150 mm (3 in. by 6 in.) piece of carborundum extra coarse emery cloth or equivalent, so that a 75 mm by 75 mm (3 in. by 3 in.) overlap occurs. The specimen shall withstand a static load of 17.8 N (4 lbs) for a period of 30 min, in accordance with ASTM D 816, method B. The slippage between the plastic sample and the emery cloth shall not exceed 25 mm (1 in.). The test shall be conducted at a temperature between 21EC (70EF) and 27EC (80EF).

1970 **(3) Adhesive Shear Strength.** Specimens shall be tested in accordance with the method described in ASTM D 638M (ASTM D 638) as modified to test the adhesive shear strength. Plastic samples cut to dimensions of 25 mm by 150 mm (1 in. by 6 in.) shall have applied to the adhesive face a 25 mm by 75 mm (1 in. by 3 in.) piece of carborundum extra coarse emery cloth, or its equivalent, so that there is a 645 mm⁵ (1 in⁵) overlap at one end of the plastic specimens. A pressure of 344.7 kPa (50 psi) shall be applied over this area for a period of 30 s. The load shall be applied by gripping each end of the test piece in a suitable tensile test machine such as a Dillon or Scott Tester. The average of the load required to break the adhesive bond shall be 4.5 kg (10 lbs) minimum. The speed of testing shall be conducted at a temperature between 21EC (70EF) and 27EC (80EF) and at a speed of 50 mm (2 in.) per minute.

(4) Bend Test. At a temperature of 27EC (80EF) the property of the plastic material shall be such that a piece 75 mm by 150 mm (3 in. by 6 in.) with the side covered by backing paper placed against a 25 mm (1 in.) mandrel may be bent over the mandrel until the end faces are parallel and 25 mm (1 in.) apart. Visual inspection shall show no apparent fracture lines in the uppermost surface.

1980 **b. Packaging.** Each package shall be marked to indicate the color of the material, specific symbol or word message, the batch number, the manufacturers name, address, and the date of manufacture.

c. Basis For Use. A type C certification in accordance with 916 shall be furnished for the preformed plastic material.

1990 **3. 100% Solids Epoxy.** This material shall be a two component material. Component A shall consist of pigment and epoxy resins formulated as set out by the manufacturer. The mixing ratio for the two components of the material shall be as recommended by the material manufacturer. This ratio shall not vary more than " 2 1/2% during the mixing operation or the application procedures of these materials.

Component A shall have the following properties:

Property	Minimum % By Weight
Pigment	
White, TiO ₂ , conforming to ASTM D 476, Type II	22
Yellow, Medium chrome yellow conforming to ASTM D 211, Type III	25
Epoxy Resins	
White	77
Yellow	70

The pigment composition shall consist of either titanium dioxide or medium chrome yellow. The epoxide value shall be tested in accordance with ASTM D 1652 and shall be 300 to 375 for both white and yellow component A, pigment free basis.

2000 Component B shall be a curing agent and shall have the amine number tested in accordance with ASTM D 2071. The amine number shall be 300 to 450.

The system, component A plus component B, shall contain no volatile solvents.

a. Material Requirements.

(1) Glass Beads. The glass beads shall be in accordance with 913.09.

2010 **(2) Abrasion Resistance.** The material shall be abraded with 1000 cycles using a 1000 gram load on CS-17 wheels in accordance with ASTM D 4060. The average loss in weight shall not exceed 82 milligrams. The tests shall be a run on cured samples which have been applied at a film thickness of 375 :m " 38 :m (15 mils " 1 1/2 mils) to code S-16 stainless steel plates. The films shall be allowed to cure at a temperature between 21EC (70EF) to 27EC (70EC) for 72 h prior to performing the indicated test. The test panel shall be unbeaded.

2020 **(3) Hardness.** The epoxy materials shall be tested in accordance with ASTM D 2240 and have a Shore D hardness of between 75 to 100. Films shall be cast on a suitable substrate at 375 :m " 38 :m (15 mils " 1 1/2 mils) in thickness and allowed to cure at a temperature between 21EC (70EF) to 27EC (80EF) for 72 h prior to performing the indicated test.

(4) Tensile Strength. The material shall be tested in accordance with ASTM D 638M (ASTM D 638). The tensile strength shall not be less than 41.4 MPa (6000 psi). The type IV specimens shall be cast in a suitable mold not more than 6.4 mm 1/4 in.) thick. The samples shall be allowed to cure at a temperature between 21EC (70EF) to 27EC (80EF) for 72 h prior to performing the indicated tests. The rate of pull shall be 6.4 mm (1/4 in.) per minute.

2030 **(5) Compressive Strength.** The material shall be tested in accordance with ASTM D 695M (ASTM D 695), except as modified herein. The cured epoxy material shall have a minimum compressive strength of 82.7 MPa (12,000 psi). The cast sample shall be conditioned at a temperature between 21EC (70EF) to 27EC (80EF) for 72 h before performing the indicated tests. The maximum rate of compression of these samples shall be 6.4 mm (1/4 in.) per minute. The sample size shall be 13 mm (1/2 in.) high by 13 mm (1/2 in.) in diameter.

2040 **(6) Weather Resistance.** The mixed epoxy compound, both white and yellow, shall be applied to 75 mm by 150 mm (3 in. by 6 in.) aluminum panels at a thickness of 375 :m " 25 :m (15 mils " 1 mils) with no glass beads and cured at a temperature between 21EC (70EF) to 27EC (80EF) for 72 h. The cured samples shall be exposed in an Environment Testing Chamber as described in ASTM G 53. The test shall be conducted for 80 h at 50EC (122EF) in alternating cycles of 4 h condensation and 4 h ultraviolet light.

SPECIMEN	REQUIREMENTS
White Material	ASTM E 97, directional reflectance a minimum 80% after exposure.
Yellow Material	Initially conform to V+ to C+ limits when visually compared with the highway yellow color tolerance chart, PR#1 of June 1965. The color of exposed material shall be within V+ , C+ , and H+ limits when visually compared.

2050 **(7) Laboratory Drying Time.** The epoxy pavement marking material shall be mixed in the proper ratio and applied at 375 :m " 38 :m (15 mils " 1 1/2 mils) wet film thickness at 24EC " 1EC (75EF " 2EF) with the proper application of glass beads. It shall exhibit a maximum no tracking time of 10 min when tested in accordance with ASTM D 711.

(8) Viscosity. Formulations of each component shall be such that the viscosity of both components shall coincide within 10% at a recommended spray temperature. Component B shall be formulated so as to have a steady and constant viscosity at temperatures recommended for spray application.

2060 **b. Materials Preparation.** Before mixing, the individual components shall be heated to the following temperatures:

Component	Temperature EC (EF)
A	32 to 38 (90 to 100)
B	21 to 38 (70 to 100)

Each component shall be stirred thoroughly prior to mixing. After mixing, the application temperature for the combined materials at the gun tip shall be between 32EC (90EF) and 38EC (100EF).

2070 **c. Packaging and Storage.** The epoxy material shall be shipped to the job site in white epoxy lined drums which are plainly marked with the manufacturer's name and address, component identification A or B, the color of the material, date of manufacture and batch number. Storage shall be at temperatures between 1.7EC (35EF) and 38EC (100EF).

The reflective glass beads shall be shipped in 22.7 kg (50 lb) moisture resistant bags. Each bag shall be marked in accordance with 913.09.

d. Basis For Use. Pavement marking material, except glass beads, furnished under this specification shall be covered by the type A certification in accordance with 916. A type A certification shall be furnished for each batch supplied. The material manufacturer shall perform all tests included elsewhere herein on each batch and shall provide these test results as part of the type A certification.

(c) Temporary Pavement Marking Tape. Temporary pavement marking tape shall be furnished in two colors and two types. It shall consist of a white or yellow reflecting film on a conformable backing which is a minimum of 100 mm (4 in.) wide, and is designed for marking either asphalt or concrete pavements.

The white or yellow reflective film on the tape shall be in accordance with highway colors. The tape shall have an average thickness, as determined by 5 micrometer readings, of no less than 0.50 mm (20 mils). The type I reflective film shall have glass beads uniformly distributed throughout the reflective film. Type I and type II reflective film shall have a reflective layer of glass beads bonded to the surface.

The tape shall be supplied in rolls ready for application and have a precoated, pressure sensitive adhesive on the backing which shall not require activation procedures. There shall be no more than three splices per 46 m (50 yds) of length. It shall be shipped in standard commercial containers so constructed as to ensure acceptance by the carrier and prevent damage during shipment and storage. It shall be capable of being stored at temperatures up to 38EC (100EF) for periods of one year without deterioration.

When the tape is applied in accordance with the manufacturer's recommended procedures, it shall be weather and traffic resistant and show no appreciable fading, lifting, or shrinkage during the useful life of the line. The material shall be of good appearance, free from cracks, and edges shall be true, straight, and unbroken. The material shall be capable of performing satisfactory for a minimum of one year.

Type I tape shall be prequalified for use. Each manufacturer shall provide the Operations Support Division with samples for field evaluation. The Department will maintain a list of approved type I tape.

Type I and type II tape furnished under this specification shall be covered by a type C certification in accordance with 916.

The minimum reflective intensity values expressed as 0.12 Candela/m²/lux (candlepower/ft²/foot candle) when tested in accordance with ASTM D 4061 shall be in accordance with the following table:

SPECIFIC LUMINANCE USING ENTRANCE ANGLE 86 DEGREE

Observation Angle	White		Yellow	
	0.2E	0.5E	0.2E	0.5E
Specific Luminance, Type 1	1770	1270	1310	820
Specific Luminance, Type 2	1000	760	820	510

2120 **(d) Raised Pavement Marker.** The raised pavement marker shall be either snowplowable, which is inset into the pavement, or temporary, which is affixed with adhesive to the pavement surface.

1. Snowplowable Raised Pavement Marker. Snowplowable raised pavement marker shall consist of a durable base to which is attached a replaceable prismatic retro-reflector for reflecting light longitudinally along the pavement from a single or from opposite directions. Both ends of the casting shall be shaped to deflect a snowplow blade upward.

2130 **a. Prismatic Reflector.** The dimensions of the reflector face shall be nominal width of 100 mm (4 in.) and a minimum vertical height of 12 mm (0.460 in.) with a slope of 30 degrees from the horizontal to the face. Minimum reflecting surface area shall be 1045 mm² (1.62 in²). The reflectors shall consist of an acrylic plastic shell filled with tightly adherent potting compound. The shell shall contain one or two prismatic faces. The reflector shall be in the shape of a shallow frustrum of a pyramid. The bottom of the reflector shall be equipped with a pressure sensitive adhesive for attachment. The shell shall be molded of methyl methacrylate conforming to Federal Specification L-P-380c, Type 1, Class 3. The filler shall be potting compound selected for strength, resilience and adhesion adequate to pass the necessary physical requirements. The adhesive shall be pressure sensitive, 100% solids, 1.0 mm (0.040 in.) thick with closed cell release paper on the bottom. Pressure sensitive adhesive shall meet the requirements of adhesive tensile strength test.

2140

Prismatic reflectors shall not be installed on bases until the adhesive in the pavement slots has properly hardened. All rust or foreign matter shall be removed from the surface of the base and the base shall be coated with a primer in accordance with the manufacturer's recommendations. The release paper shall be peeled from the butyl adhesive bottom of the reflector. The reflector shall be inserted into the recessed attachment area and a downward pressure of 667 N (150 lbs) shall be applied for 3 s.

2150

(1) Optical Performance. In order to perform the optical performance test, the following definitions shall apply. Horizontal incident angle shall mean the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the reflector. Reflective intensity shall mean candlepower of the return light at the chosen divergence angle for each 10.76 Lux (footcandle) of illumination at the reflector on a plane perpendicular to the incident light.

2160 A steel wool abrasion test shall be performed by forming a 25 mm (1 in.) diameter flat pad using No. 3 coarse steel wool. The steel wool pad shall be placed on the reflector lens, a load of 22.7 kg (50 lbs) shall be applied, and the entire lens surface shall be rubbed 100 times.

After abrading the lens surface, the reflective intensity of each white reflecting surface at 0.2 degree divergence angle shall meet the following requirements when the incident light is parallel to the base of the reflector.

HORIZONTAL INCIDENT ANGLE	MINIMUM REFLECTIVE INTENSITY
0E	0.279 cd/lx (3.0 Candlepower/footcandle)
20E	0.1115 cd/lx (1.2 Candlepower/footcandle)

2170 The reflective intensity for yellow reflectors shall be 60% of the value for white. The reflective intensity for red reflectors shall be 25% of the value for white.

A sample consisting of 100 markers shall be submitted and 23 will be tested. The reflectors to be tested shall be located with the center of the reflecting face at a distance of 1.5 m (5 ft) from a uniformly bright light source having an effective diameter of 7 mm (0.28 in.). The photocell width shall be an annular ring 9 mm (0.37 in.) inside diameter and 12 mm (0.47 in.) outside diameter and shall be shielded to eliminate stray light. The distance from light source center to the photocell center shall be 5 mm (0.21 in.). If a test distance of other than 1.5 m (5 ft) is used, the source and receiver shall be modified in the same proportion as the test distance. Failure of more than 4% of the sample's reflecting faces shall be the cause for rejection.

2180 **(2) Seal Test.** A sample of 50 units shall be submerged in water at room temperature and subjected to a vacuum of 125 mm (5 in.) mercury for 5 min. After restoring atmospheric pressure, the units shall be left submerged for an additional 5 min. The unit shall be examined for water intake and failure of more than one unit shall be cause for rejection.

2190 **(3) Heat Resistance Test.** Three reflectors shall be tested for 4 h in a circulating air oven at 80E " 3EC (175E " 5EF). The test specimens shall be placed in a horizontal position on a grid or perforated shelf permitting free air circulation. At the conclusion of the test the samples shall be removed from the oven and permitted to cool in air to room temperature. After exposure to heat, the samples shall show no significant change in shape and general appearance when compared with corresponding unexposed control standards. Failure of one or more units shall be cause for rejection.

(4) Strength Test. A random sample of three reflectors shall be selected for test purposes. The reflector base shall be positioned at the center of a flat steel plate which has a minimum thickness of 13 mm (0.5 in.) and a minimum outside diameter of 114 mm (4.5 in.). A load shall be applied to the top of the reflector through a 25 mm (1 in.) diameter by 25 mm (1 in.) high metal plug centered on the top of the reflector. The rate of loading shall be 5 mm (0.2 in.) per minute. The reflector will be rejected if there is either breakage or significant deformation of the reflector at any load of less than 8896 N (2000 lbs).

(5) Impact Test. The red lens shall not be subjected to impact test. A random sample of 20 lenses shall be selected from each lot of reflectors.

The reflectors shall be placed in a convection oven at 55EC (130EF) for 1 h. The reflectors shall be removed from the oven and the reflective face shall be immediately impacted by allowing a 0.2 kg (0.42 lbs) dart fitted with a 6 mm (0.25 in.) radius spherical head to drop 460 mm (18 in.) perpendicularly onto the center of the reflective surface. Cracks in the impact area shall be concentric in appearance. There shall be no more than two radial cracks longer than 6 mm (0.25 in.). There shall be no radial cracks extending to the edge.

If 18 lenses of the test samples meet the above requirements, the lot shall be acceptable. Failure of four lenses of the sample shall be cause for rejection of the lot. If three lens fail, a resample of 20 additional lens shall be tested for failure. Failure of more than one lens of the resample shall be cause for rejection of the lot.

(6) Temperature Cycling Test. A random sample of 20 lenses shall be selected from each lot of reflectors. The samples shall be subjected to three cycles of 60EC (140EF) for 4 h followed by -7EC (20EF) for 4 h. There shall be no cracking nor delamination following temperature cycling.

If 18 lenses of the test samples meet the above requirements, the lot shall be acceptable. Failure of four lenses of the sample shall be cause for rejection of the lot. If three lenses fail, a resample of 20 additional lenses shall be tested for failure. Failure of more than one lens of the resample shall be cause for rejection of the lot.

(7) Adhesive Tensile Strength Test. A standard 100 mm by 50 mm by 12 mm (4 in. by 2 in. by 0.46 in.) reflector with pressure sensitive adhesive on the bottom shall be adhered to a flat 3.0 mm (0.12 in.) carbon steel test plate. The plate shall be primed in accordance with 913.14(d)1a, and the reflector shall be applied with a minimum application pressure of 41 kPa (60 psi). Both the top of the reflector and bottom of the flat plate shall have fastened to it an appropriate coupling device to ensure compatibility with the tensile testing device. The test sample shall then be tested in the tensile mode at 50 mm (2 in.) per minute pull rate. Minimum load to produce failure shall be 566 N (125 lbs) at 21EC (70EF). Any load below 566 N (124 lbs) is a failure and shall be cause for rejection of the lot.

(8) Basis for Use. The prismatic reflector shall be covered by a type B certification in accordance with 916.

b. Cast Metal Base. The base shall be a ductile iron casting made of modular iron in accordance with ASTM A 536, Grade 70-50-05 hardened to 52-54 RHC. The cast iron base shall be marked with the manufacturer's name and model number. The maximum dimensions shall be 51 mm (2.00 in.) high, 152.0 mm (6 in.) wide and 254.0 mm (10.00 in.) long.

2250 The exposed height of the casting after installation shall not exceed 13 mm (0.50 in.). The bottom of the casting shall have two parallel keels and a shaped web designed to fit into an accurately sawed, grooved slot in the pavement surface as shown on the plans.

(1) Epoxy Adhesive. The epoxy adhesive shall be in accordance with AASHTO M 237, Type IV, Table 3 with respect to composition and performance. For sampling purposes, a batch shall consist of a single charge of all components into a mixing chamber.

2260 **(2) Basis for Use.** A type B certification in accordance with 916 shall be furnished for the epoxy material. A type C certification in accordance with 916 shall be furnished for the cast metal base for the pavement markers.

c. Precast Cement Concrete Base. The base shall be made of cement concrete with a compressive strength of 34.5 MPa (5000 lbs) when tested in accordance with ASTM C 39. The maximum dimensions shall be 51 mm (2.00 in.) high, 152.0 mm (6 in.) wide and 254.0 mm (10 in.) long. The maximum exposed height of the base after installation shall be 13 mm (0.50 in.).

2270 **(1) Adhesive for Precast Concrete Base.** This adhesive shall be quick setting magnesium phosphate concrete patching material with high strength and high bonding qualities. This material shall be used between -1EC (30EF) and 32EC (90EF) and in thicknesses varying from 13 mm (1/2 in.) to full depth.

The material may be a complete dry mix requiring only the addition of either water or a liquid activator just prior to mixing and use. The material shall not contain sufficient soluble chloride nor soluble sulfates to cause corrosion of reinforcing steel or damage to portland cement concrete.

2280

The adhesive shall have an initial setting time of 10 min in accordance with ASTM C 266. The compressive strength shall be in accordance with ASTM C 109 and as listed.

TIME	COMPRESSIVE STRENGTH
2 h	10.3 kMa (1500 psi) min
24 h	27.6 MPa (4000 psi) min
7 days	41.3 MPa(6000 psi) min

The adhesive shall have a durability factor of not less than 80 after being subjected to 300 cycles of the freeze and thaw test in accordance with ASTM C 666, Procedure B.

2290

The adhesive shall be suitable for use with hand tools and shall not require special curing procedures.

(2) Packaging. The patching material adhesive shall be packaged in strong moisture resistant bags or other suitable containers capable of withstanding normal shipping and handling without damage. The container shall protect the material from deterioration for a period of one year when stored in a dry condition. Mixing instructions shall be printed on each container.

2300

(3) Basis for Use. A type C certification in accordance with 916 shall be furnished for the precast cement concrete base. A type B certification in accordance with 916 shall be required for the marker adhesive patching material.

2. Temporary Raised Pavement Marker. A temporary raised pavement marker shall consist of a shell, a reflective element and an adhesive. The shell shall be black or the same color as the pavement marking being supplemented or replaced. The reflective element shall be either a reflective prismatic lens or reflective sheeting. A uni-directional marker shall meet the visual requirements of this specification when viewed from the front of the marker and a bi-directional marker shall meet the visual requirements when viewed from either direction. Two uni-directional markers placed back to back are an acceptable alternate for a bi-directional marker.

2310

The dimensions of the front view of the marker shall be as follows:

DIMENSION	MINIMUM	MAXIMUM
Width of marker shell	97 mm (3.8 in.)	
Height of marker shell without adhesive	13 mm (0.5 in.)	
Height of marker shell with adhesive		25 mm (1.0 in.)
Area of prismatic lens reflecting surface	194 mm ² (.30 in ²)	
Area of sheeting reflecting surface	645 mm ² (1.0 in ²)	

a. Optical Requirements. The white and yellow reflective elements shall have the initial minimum reflectance values specified in the following tables when measured in accordance with ASTM E 809. The photometric characteristic to be measured shall be the coefficient of luminous intensity. This coefficient shall be expressed as candelas per lux (candlepower per footcandle). The entrance angle vertical component, Beta 1, shall be the clockwise angle formed from the vertical half plane, passing through the bottom front edge of the reflective element, to the face of the reflective element when viewed from the right side.

TABLE 1
REFLECTIVE SHEETING ELEMENT FOR GRADE 2 MARKERS

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity Candelas/lux (Candlepower/foot candle)	
		White	Yellow
0.2	-4	0.0929 (1.0)	0.0558 (0.60)
0.5	-4	0.0372 (0.4)	0.0223 (0.24)

TABLE 2
REFLECTIVE SHEETING ELEMENT FOR GRADE 1 MARKERS

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity Candelas/lux (Candlepower/foot candle)	
		White	Yellow
0.2	-4	0.0929 (1.00)	0.0558 (0.60)
0.5	+ 20	0.0372 (0.4)	0.0223 (0.24)
0.5	-4	0.0372 (0.4)	0.0223 (0.24)

TABLE 3
REFLECTIVE PRISMATIC LENS ELEMENT

Observation Angle (degrees)	Entrance Angle Horizontal Component Beta 2 (degrees)	Coefficient of Luminous Intensity (candelas/lux (Candle power/foot candle)	
		White	Yellow
0.2	+ 20	0.00372 (0.04)	0.0223 (0.24)
0.2	0	0.093 (1.0)	0.0223 (0.24)

The grade two marker does not require daytime visibility and target value. The shape, color and finish of the grade one marker shall provide an adequate diffused specular daytime signal. A diffused specular daytime signal will be considered adequate when the area of the horizontal projection, as determined from a point of projection of the front view of the marker less the projected areas of the reflective element and non-specular materials, is a minimum of 92900 mm² (144 in²). A minimum of 61900 mm² (96 in²) of this projection shall be attributable to that portion of the front view greater than 3 mm (0.125 in.) above the reference plane. For purposes of this requirement, the reference plane shall be the horizontal plane passing through the base of the marker and the point of projection shall be the point located 149.4 m (490 ft) horizontally in front of the marker and 1.1 m (42 in.) above the reference plane.

b. Strength Requirements. The marker shall withstand a 44.5 kN (10,000 lbs) load without cracking or permanent deformation. The testing procedure shall consist of centering a marker between the flat paralleled platens of a compression testing machine. A flat piece of 50-60 Shore A durometer rubber 150 mm by 150 mm by 10 mm (6 in. by 6 in. by 3/8 in.) shall be centered on top of the marker. The load shall be slowly applied through the rubber to the top of the marker. Failure shall constitute either cracking or permanent deformation of the marker at any load less than 44.5 kN (10,000 lbs).

c. Adhesive. The adhesive shall be compatible with the marker materials and shall not cause deterioration of the marker or concrete and HMA pavements. The three types of acceptable adhesives shall be a pre-applied pressure sensitive adhesive, an adhesive pad or a asphalt adhesive.

The asphalt adhesive shall be used only on concrete pavement surfaces and on HMA pavement surfaces which receive an additional pavement course of at least 19 mm (3/4 in.) thickness.

Pre-applied pressure sensitive adhesive shall be pre-qualified for use from a field evaluation.

The adhesive pad shall be sized to fit the marker's dimensions and shall consist of pressure sensitive, 100% solids, approximately 1.0 mm (0.04 in.) thick, with closed cell release paper on each side. The pressure sensitive adhesive, when applied with a minimum application pressure of 414 kPa (60 psi), shall possess a minimum tensile or shear strength of 103 kPa (15 psi) at 21EC (70EF) ambient air temperature. An adhesive primer shall be used to promote optimum adhesion when the adhesive pad is placed on old asphalt or concrete surfaces that have one or more additional courses. The adhesive primer shall be as recommended by the manufacturer of the adhesive pad. The adhesive primer shall not be used on the surface course.

The asphalt adhesive shall be applied using an appropriate melter or applicator and shall be in accordance with the following:

CHARACTERISTIC	REQUIREMENT
Specific gravity	1.80
Mass per cubic meter (Weight per cubic foot)	1762 kg (110 lbs)
Flash point per ASTM D 92	265EC (509EF)
Bitumen content per ASTM D 2172	25-30%
Filler content (by subtraction)	70-75%
Filler particle size	Over 85% passing 200 mesh sieve (75 :m)
Penetration at 25EC (77EF) per ASTM D 5	12 " 4
Softening point (Ring & Ball) per ASTM D 36	105EC " 3EC (221EF " 5EF)
Recommended pouring temperature	204EC - 218EC (400 - 425EF)
Shelf life	2 years
Packing	Silicone lined cardboard boxes containing approximately 28.1 kg (62 lbs) each

Note: Material shall not contain rubber polymers.

2380

d. Acceptance Evaluation. Markers shall be prequalified for use and each manufacturer shall provide the Procurement and Distribution Division, Evaluation Unit with samples for a field evaluation. The Department will maintain a list of approved temporary raised pavement markers.

e. Basis for Use. Grade 1 and grade 2 markers furnished under this specification shall be covered by a type C certification in accordance with 916.

913.15 Traffic Signal Materials and Equipment.

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(a) Traffic Signal Controller and Cabinet.

1. Model Approval. Each model of controller and its cabinet will be tested, evaluated, and approved prior to use. Testing, evaluation, and approval will require a minimum of six months to perform. The period of evaluation will commence when the Department receives the preliminary product evaluation form accompanied by the product brochure, operational manual, maintenance manual, and documented theory of operation. The Procurement and Distribution Division will advise the manufacturer or vendor, in writing, of the date to deliver the controller and cabinet, for which model approval is requested, to the Procurement and Distribution Division. Certification in accordance with 913.15(a)6.f.(2), shall be received at the Procurement and Distribution Division a minimum of two weeks prior to the date of delivery of the controller and cabinet. Certifications in accordance with 913.15(a)6.f.(1), schematics for the controller and cabinet, operational manuals, theory of operation and parts lists shall be furnished with the controller when it is submitted to the Procurement and Distribution Division for evaluation and testing. The controller and cabinet will undergo the bench test in accordance with 913.15(a)4. A controller or control unit that fails the bench test procedure three times will be rejected and will not be placed upon the approved products list, nor will it be considered for future evaluation without documented changes to design. A list of approved models will be maintained by the Department. Only models from the approved list of control equipment in effect as of the date of letting, or as otherwise specified, shall be used in the contract. Continued failure and repeated malfunctions of an approved controller or control equipment shall be cause to remove that model from the Department's list of approved products.

A design change to an approved model of controller will require a resubmittal of the model for testing, evaluation, and approval. Permanent addition or removal of component parts or wires will be considered to be a design change.

2. Controllers or Control Units Furnished and Installed by the Contractor. A controller with all components of equipment, necessary for an operating signal, wired into a cabinet will be a control unit. The Contractor shall prepare three packets for each control unit and provide these packets to the Engineer. Packet 1 shall consist of one complete set of wiring and schematic diagrams for the control unit and its appurtenances and a listing of model name/number and serial number of the removable equipment that can be readily exchanged or replaced, such as controller enclosure, controller modules, load switches, conflict monitor, detectors, and flashers. Packets 2 and 3 shall each consist of the same items as in Packet 1 plus a descriptive parts list and instruction and maintenance manuals that include the manufacturer's data sheets on each different type of I. C. chip being used, connection diagrams, voltage checks and the theory of operation. Each packet shall be labeled with the name of the intersection, the Contract Number, the Commission Number and the date of installation. Packet 1 will be forwarded to the Procurement and Distribution Division, packet number 2 will be retained in the controller cabinet, and Packet 3 will be retained by the District Traffic Office.

The Contractor shall be responsible for all costs associated with vendor or manufacturer warranty service until acceptance of the contract, or acceptance of that portion of the contract where the traffic control equipment is installed.

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3. Blank.

4. Bench Testing.

The Department's Traffic Signal Control Bench Test Procedures, which are used for bench testing of traffic signal controllers, cabinets, and related equipment are on file and available upon request.

During bench testing a control unit will be considered as failed if one of the following conditions are encountered during the physical or operational test procedure:

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a. The controller unit skips intervals, or phases, places false calls, presents false indicator lights, does not follow the prescribed sequence or exhibits changes in timing beyond the tolerances of the specifications.

b. The load switches produce incorrect signal indications.

c. The conflict monitor fails to perform in accordance with the specifications of the requisition or contract.

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d. Auxiliary equipment such as pre-emptors, coordinators, or detectors do not operate in accordance with the specifications.

e. The wiring for the interface of any items set out above is defective or incorrect.

If the control unit fails the bench test procedure, the control unit shall be removed from the Procurement and Distribution Division for repairs and returned to the Traffic Support Center for retesting. The cover letter for the resubmittal of the control unit for retesting shall include an explanation of why the unit failed and what specific repairs were made.

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A written test report will be provided for each control unit tested. A representative of the manufacturer or vendor may be present during the bench testing procedure.

5. Pretimed Solid State Digital Controller. The following requirements are the minimum for the design and operation of a pretimed solid state digital, keyboard entry or keyboard entry backlit liquid crystal display menu-driven display type controller. The controller shall be capable of operating as a master or secondary control unit having four cycles, three offsets and four splits per cycle, and a minimum of four signal plans with individual control of 24 signal circuits, with an option of a total of 40 signal circuits, in each of 24 intervals. Controller, cabinet, and component parts shall be in accordance with NEMA Standards TS-1, all provisions contained herein, and the Department's traffic signal control bench test procedures. The requirements herein and the test procedures shall govern over NEMA standards.

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2490 **a. General.** The controller shall have a keyboard entry or keyboard entry backlit liquid crystal display menu-driven type with internal pre-emption, time base coordination, telemetry, printer, and interconnect modules. The controller unit shall contain a printer interface module, which permits a hard copy printout of all keyboard settings. The unit shall employ circuit designs, consistent with the latest techniques, using a microprocessor to implement the control logic.

The keystroke buttons shall be clearly marked as to function. The controller shall be programmable to permit initialization in any interval after a defined power interruption or reset by the conflict monitor.

2500 All data entry display windows shall be liquid crystal design. The display shall be a high resolution type display such that the display shall be readable on a plane located 0.6 m (2 ft) in front of, and parallel to, the display window. As a minimum, the display shall be readable throughout a vertical 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the horizontal line that is perpendicular to the center of the display window. Also, the display shall be readable throughout a horizontal 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the vertical line that is perpendicular to the center of the display window. The backlit liquid crystal display shall have a diffusion type lens or membrane to reduce its surface glare. All menu driven, data entry displays shall be backlit. The display for the menu driven controller shall be a minimum of four lines
2510 with 40 characters per line. All programming buttons and indicators pertinent to the operation of a phase shall be on the front of the controller. The display windows shall be capable of displaying the cycle length, offset, split, and any other variable functions or controller settings.

Materials, conductors and component identification for all printed circuit boards shall be in accordance with NEMA Standards TS-1-14.2.3. Where practical, components shall be individually soldered directly to the printed circuit boards except for the memory elements, such as ROM, RAM, and PROM, which shall be socket mounted.

2520 All volatile memory chips and modules shall have battery back-up to protect any operator programmed data for a period of at least 60 days without 115 volt, 60 hertz AC input to the controller unit. Battery back-up may be achieved with either a rechargeable battery maintained in a charged state through a trickle charge or a nonrechargeable battery with a minimum shelf life of 10 years. Batteries shall be capable of being disconnected for shelf storage of the controller unit. An indicator shall be provided on the front of the controller to indicate that the battery is connected and operating properly. If a nonrechargeable battery is supplied, an indicator shall also be provided to show a low battery charge. The memory module, when removed from the
2530 mainframe, shall maintain all programmed data for at least 48 h.

Any external battery within the controller unit shall be turned off or disconnected during shipment and storage.

All electrical components such as integrated circuit chips, transistors, diodes, triac, and capacitors shall be of such quality that they function properly under the environmental conditions experienced in field operation. All printed circuit boards shall be protected with a rosin coating. Fusing shall be on the front panel of the controller and shall provide protection to the controller from internal or external overload.

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The motherboard in the mainframe shall be capable of accepting all plug-in modules, including additional modules to provide for 40 signal circuits, necessary for the operation of the controller. All plug-in modules shall be equipped for easy removal or installation without the use of tools. All plug-in circuit boards shall be readily accessible for maintenance. Extender boards may be used for this purpose. As a minimum, all circuit boards shall be edge labeled with the first and last number, the first and last letter, and the first and last double letter if applicable, corresponding to the pin connector position. All modules shall each be removable without removing any other module. All hinges used shall have stainless steel pins.

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The controller unit shall be able to operate as a master controller or a secondary controller without requiring any changes in the unit itself. When used as a master controller, it shall not be required to program the units offsets to zero. The controller unit shall be capable of operating in an existing pretimed interconnected systems, which may have an electromechanical interrupter utilizing 115 volts, 60 hertz, AC. Cycle, offset, and split selectability shall be either by application of 115 volts, 60 hertz AC to the fuse panel or manually from the keyboard. Use of 115 volts AC Interconnect to a 24 volts DC logic interface is acceptable. As a minimum, the controller shall be capable of accepting nine conductors for interconnect, two conductors for cycle 1-4 selection, three conductors for reset 1-3 selection, two conductors for split 1-4 selection, and one conductor each for flash and common.

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With each controller unit and cabinet there shall be furnished three complete sets of wiring and schematic-diagrams, two descriptive parts lists, two instruction and maintenance manuals that include the manufacturer's data sheets on each different type of integrated circuit chip being used that has not been previously submitted to and on file at the Procurement and Distribution Division, connection diagrams, voltage checks and the Theory of Operation. The instructions manual shall contain explicit programming procedures for all required features and any additional features incorporated in the controller's design. All schematics shall also include numbered test points, where applicable, with operating voltages.

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Serial number and model numbers shall be permanently applied on the face or front of all removable components of the controller where it is easily readable, without removing or disconnecting the component. Serial number and model number of the main frame shall be permanently applied externally near the front panel.

b. Controller Requirements. The controller shall be capable of providing four cycle lengths with a minimum time setability from 10 to 255 s in increments of 1 s. Transfer from one cycle to another cycle shall occur at the end of the interval in effect at the time of request for transfer if that interval is programmed for transfer. Cycle selection of any of the four cycles, from a remote location, shall be accomplished by use of no more than three conductors.

The unit shall be capable of providing three individually programmable offsets for each cycle with a minimum time setability from 0 to 250 s in 1 s increments. The offset to be in effect shall be selected by activation of one of the three Reset inputs of the controller. Energization of a Reset input shall place that offset in effect independent of timing plan selection. Momentary de-energization, for a period of 3 to 5 s, of a Reset input shall define the system reference or synchronization.

The controller shall have program selected capabilities of a minimum of two methods of offset seeking transfer, shortway or dwell.

Shortway offset transfer is the transfer from one offset to another by shortening or lengthening the permitted intervals of the signal plan so that no offset change may exceed 25% of the cycle length in one cycle. The new offset shall never be more than 50% away from the existing offset. The permitted intervals, whose duration may be varied, shall be specified in the signal plan. During shortway offset seeking, no interval shall time less than the minimum programmed, in the signal plan, for that interval.

Dwell offset transfer is the transfer from one offset to another by holding in a programmed interval up to a maximum programmed duration. The controller shall be capable of programming the maximum dwell time between 1 and 250 s in 1 s increments. Only one maximum dwell interval shall be timed between transitions of Reset input lines. The unit shall be capable of accepting interrupter pulses.

The controller shall provide the capabilities of four splits for each programmed cycle. Each split for each cycle shall consist of a programmed number of intervals, variable up to a maximum of 24. If split transfer is programmable, transfer from one split to another shall occur in the intervals programmed to allow split transfer. If split transfer is not programmable, transfer shall occur at the zero point of the cycle. Split selection of any of the four splits, from a remote location, shall be accomplished by the use of no more than three conductors.

A minimum of 24 signal intervals shall be provided for each combination of cycle and split. The intervals shall be individually programmable minimum time setability, selectable from 0 to 12.7 s in increments of 0.1 s or from 0 to 127 s in increments of 1.0 s for each cycle and split. The controller shall be capable of copying the timing values for any cycle and split into any other cycle and split in one operation.

If the controller can indicate time settings greater than required, the greater time settings shall be active when entered into the controller.

2630 The controller shall be capable of implementing any one of up to four different signal plan sequences. The signal plan shall be either externally selectable by placing logic ground to the input terminal or manually selectable through the keyboard. During any controller cycle, it shall be possible to operate in any of the four signal plans, if the signal plans are compatible. Signal plan transfer shall occur in the next interval programmed for signal plan transfer. Each signal plan shall have at least one interval to enable safe transfer between signal plans. The controller unit shall operate in accordance with the programmed values for the selected cycle, offset and split, regardless of the signal plan in effect. Signal plan PROM programming shall effect the On-Off-Flash condition of the signal circuits, and minimum and backup timing of each interval.

2640 The unit shall provide the capabilities for a minimum of two detector inputs which can be programmed for Lock, Non-Lock, or Recall modes. The detector inputs shall provide a means to enter vehicle or pedestrian demand. When activated, these inputs may add intervals up to a total of 24 intervals to the cycle.

The unit shall provide the capabilities for a minimum of two preempt inputs. These inputs, either of which is activated, shall cause initialization of the selected preemption sequence which shall remain in effect until the input is removed.

2650 The controller unit shall have an internal time clock with capabilities of programming for time-of-day, day-of-week, and week-of-year. The time clock shall allow selection of cycles, splits and offsets through the time clock, the hardwire interconnect, the communication module, manual selection through keyboard entry, or a combination of these functions.

The controller shall have internal communication and telemetry with at least FSK 1200 Baud rate capable of transmitting on Bell 3002 four wire conductor with 600 ohm line impedance.

The controller unit shall provide capabilities for the following inputs: Stop Timing, External Start, Start-up Flash, Interval Advance, Manual Control Enable, Remote Flash, and System or Computer Control.

2660 Stop timing shall cause all timings to be discontinued. When stop timing is removed, timing shall resume from the point of interruption.

External start shall cause the controller to assume its programmed initialization conditions and commence normal operations upon removal of the input.

2670 Interval advance shall cause the controller to advance to the next interval in sequence, provided the manual control enable input is not energized. The actual advance shall occur on the trailing edge of the actuation. The duration of any interval shall be capable of being shortened without regard to the programmed minimum for the interval with the interval advance input active.

Manual control enable shall cause the controller to operate in the manual mode of operation. The transfer from automatic to manual mode operation and back to automatic operation shall occur immediately upon activation or de-activation of manual control enable.

2680 When operating in the manual mode, the same color sequence, as provided in automatic control, shall be displayed. Duration of all programmed variable intervals shall be controlled by operation of the interval advance input. Duration of programmed non-variable intervals shall not be less than the minimum time specified in the signal plan for such intervals. Operation of the interval advance input shall not advance the controller out of these intervals.

Synchronization with the system shall be maintained during manual mode operation. When transferring back to automatic operation, the controller shall resume timing of the interval at the point in the selected timing plan that corresponds to the beginning of the interval being displayed when the transfer occurs.

2690 Remote flash shall cause the controller to transfer to flashing operation when an AC+ signal is applied to the unit's fuse panel by an external source. The police panel switch shall cause the controller to go to immediate flash. Synchronization with the system master shall be maintained during flashing operation, if applicable. Upon de-activation of remote flash, transfer to cyclic operation shall be immediate and the unit shall display the interval that was programmed for exit from flash.

System or computer control, when activated, shall control the duration of the programmed variable intervals, except when pedestrian or vehicle calls are not placed on the detector inputs.

2700 **c. Spare Modules.** All spare modules shall be in accordance with the appropriate sections of this specification.

d. Controller Enclosure. The enclosure shall be of adequate physical strength to protect the components during normal physical handling. Fusing, keypad, liquid crystal display, and input-output connectors required for the operation and standard field adjustments shall be mounted on the front panels.

2710 The main frame shall be completely equipped and wired as a complete pretimed controller so that no additional hardware or wiring is required. The front panel of the controller shall be positively fastened to the frame. Special tools shall not be required to remove or replace modules or plug-connected printed circuit boards.

e. Power Requirements. The controller shall operate in accordance with NEMA Standard TS-1-2.

f. Certification of Traffic Control Units. Certification of traffic control units shall be in accordance with 913.15(a)6f.

2720 **g. Warranty.** The warranty for traffic control units shall be in accordance with 913.15(a)6g.

6. Traffic Actuated Solid State Digital Controller. The following requirements are the minimum for the design and operation of an 8 phase fully-actuated solid state, digital, menu-driven with backlit liquid crystal display controller. Controller, cabinet, and component parts shall meet NEMA Standards TS-1, all provisions contained herein, and the Department traffic signal control bench test procedures. The requirements herein and the test procedures shall govern over NEMA standards.

2730 **a. General.** The controller shall be keyboard entry, menu-driven with liquid crystal type display. The controller shall have internal preemption, time base coordination, telemetry, printer and interconnect modules. The microprocessor shall utilize nonvolatile memory devices. If "0" Powered Ram is utilized, the shelf life, with load, shall be a minimum of 10 years. Time base coordination shall use battery backed RAM to maintain the system clock and power outage. Any external battery within the controller unit shall be turned off or disconnected during storage and shipment. With each controller unit and cabinet, there shall be furnished three complete sets of wiring and schematic diagrams, two descriptive parts lists, two instruction and maintenance manuals that include the manufacturer's data sheets on each different type of integrated circuit chips being used that has not been previously submitted to and on file at the Procurement and Distribution Division, connection diagrams, voltage checks, and the Theory of Operation. The instruction manual shall contain explicit programming procedures for all required NEMA features and any additional features of which are incorporated into the controller design. All schematics shall also include numbered test points, where applicable, with operating voltages.

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Serial number and model numbers shall be permanently applied on the face or front of all removable components of the controller where it is easily readable, without removing or disconnecting the component. Serial number and model number of the main frame shall be permanently applied externally near the front panel.

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b. Controller Requirements. The time settings shall be in accordance with NEMA Standards TS-1-14. If the controller can indicate time settings greater than required, the greater time settings shall be active when entered into the controller. A minimum of two maximum timing parameters shall be supplied on all phases of the controller and shall function when activated.

The controller shall be capable of 2 through 8 phase programming and shall be capable of accepting an interrupter pulse on any coordinated phase.

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Pedestrian timing shall be provided on all phases of a controller.

2770 The backlit liquid crystal display window shall consist of a minimum of four lines with 40 characters per line. The display shall be a high resolution type display such that the display shall be readable on a plane located 0.6 m (2 ft) in front of, and parallel to, the display window. As a minimum, the display shall be readable throughout a vertical 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the horizontal line that is perpendicular to the center of the display window. Also, the display shall be readable throughout a horizontal 60 degree angle that contains a minus 15 degree angle to a plus 30 degree angle measured from the vertical line that is perpendicular to the center of the display window. The backlit liquid crystal display shall have a diffusion type lens or membrane to reduce its surface glare.

The Time Base Coordinator shall operate such that the line function has the capability to provide output for a minimum of four time of day functions during the same event time.

2780 Controllers shall be capable of servicing eight phases. The control unit, when delivered, shall be programmed to initialize in phase 2 and phase 6 green. The controller shall be keyboard programmable to permit initialization in any phase after a defined power interruption or reset by the conflict monitor. The following recall functions shall be a minimum and shall show functional status on the liquid crystal display.

- 2790
- (1) lock detection
 - (2) maximum recall
 - (3) minimum recall
 - (4) non-lock detection
 - (5) pedestrian recall

Keystroke buttons shall be clearly marked as to function.

All indicators shall be liquid crystal design. All programming buttons and indicators pertinent to the operation of a phase shall be on the front of the controller. The controller shall have complete phase skipping capabilities. Dual ring, eight phase controllers shall have single entry operation.

2800 Controllers shall have keyboard programmable overlaps in accordance with NEMA Standards TS-1-14.3.7. All inputs and outputs from the controller shall be in accordance with NEMA Standards TS-1-13 and shall be accessible within the cabinet at the output terminal facility.

All electrical components such as integrated circuit chips, transistors, diodes, triac, and capacitors shall be of such quality that they function properly under the environmental conditions experienced in field operation. All printed circuit boards shall be protected with a rosin coating. As a minimum, all plug-in circuit boards shall be edge labeled with the first and last number, the first and last letter, and the first and last double letter if applicable, corresponding to the pin connector position. Input-output pin connectors and MS connectors shall be as specified in NEMA Standards TS-1. Fusing shall be on the front panel of the controller and shall provide protection to the controller from internal or external overload.

c. Spare Modules. All spare modules shall be in accordance with the appropriate sections of this specification.

d. Controller Enclosure. The enclosure shall be of adequate physical strength to protect the components during normal physical handling. Fusing, keypad, liquid crystal display and input-output connectors required for the operation and standard field adjustments shall be mounted on the front panels.

The main frame shall be completely equipped and wired as a complete 8 phase NEMA controller so that no additional hardware or wiring is required. The front panel of the controller shall be positively fastened to the frame such that no special tools shall be required to remove or replace modules or plug-connected printed circuit boards.

e. Power Requirements. The controller shall operate in accordance with NEMA Standard TS-1-2.

f. Certification of Traffic Control Units. The following certifications shall be furnished in accordance with the applicable provisions of 916.

(1) Certification of a Production Run Model. A Certification for a model of control unit shall be on file with the Department. A production run model shall be tested in accordance with, and comply with, all requirements of the NEMA Standards TS-1, Part 2, including shock and vibration. A certification of a production run model will be valid for a maximum period of four years from the date of testing or unless a significant change is made in the controller. If a significant change is made a new certification shall be submitted. A significant change shall be the addition or deletion of any function or feature in the control unit, or any major change to the circuitry in the control unit.

(2) Certification of Environmental Testing. A certification shall be furnished with each control unit approval indicating it has been tested and is in accordance with the following tests from NEMA Standards TS1-2.

- TS1-2.2.03- Test Procedure **C** Transients, Temperature, Voltage, and Humidity.
- TS1-2.2.04- Cabinet ventilation tests.
- TS1-2.2.07- Power interruption test.
- TS1-2.2.08- Timing accuracy tests.
- TS1-2.2.09- Signal conflict monitoring tests.

The cabinet requirements in 913.15(a)7 shall be applicable during the appropriate tests.

The certification shall specify the model and serial number of the following components: cabinet, controller main frame, phase modules, ring modules, conflict monitor, load switches, flasher, and all specified auxiliary control equipment.

A complete log of each test for every controller shall be maintained. The log shall show which, if any, controller component failed during the test, when it failed, and what steps were taken to repair the controller. The log shall include the date of testing, name and title of person conducting the tests, a record of conditions throughout the tests, and a temperature and humidity vs time chart. The maximum revolution of any chart shall be 24 h. The chart shall be from a recording machine used to monitor the status of the environmental chamber during testing.

g. Warranty. A standard manufacturer's warranty shall be furnished for each traffic signal control unit which is furnished and installed. The effective date for the beginning of the warranty shall be the turn-on date shown on Form I.C. 636A. The warranty shall be provided prior to final acceptance.

Each traffic signal control unit purchased by the Department shall have a minimum two year operational warranty or the manufacturer's standard warranty, whichever is longer. The two year warranty shall begin on the date the control unit is received at the Procurement and Distribution Division. The vendor or manufacturer shall be responsible, during the warranty period, for transportation costs to and from the Procurement and Distribution Division for items requiring warranty service.

Each traffic signal control unit purchased by the Department shall have a two year operational warranty. The two year warranty shall begin on the date the control unit passes the Traffic Signal Control Bench Test Procedures.

Continued failure and repeated malfunctions of an approved model of controller shall be cause to remove that model from the Department list of approved models.

7. Cabinet Requirements for Traffic Signal Controllers.

2890 **a. General.** The cabinet and the shelf, if needed, shall be fabricated of aluminum. The cabinet shall be 3 mm (0.125 in.) minimum thickness sheet aluminum or 6 mm (0.25 in.) minimum thickness die-cast aluminum. The cabinet exterior and interior including shelves, shall have a sandblasted, roughened, or chemically etched finish that reduces gloss, reflection, and glare.

2900 The main cabinet door shall use a Corbin Lock No. 2 and the lock shall be furnished with two No. 2 keys. The door shall be capable of being opened and stopped in at least the following two ranges of degree opening as measured from the face of the cabinet door on the hinged side, 80 to 100 degrees, and 150 to 180 degrees. The door shall be hinged on the left or right side of the cabinet.

 The cabinet shall have a police door within the main door. The police door shall use a standard Corbin Police panel lock. The police door shall be weathertight. Two keys shall be furnished for the police door.

2910 In a cabinet used for a pretimed controller, the police door shall contain three separate switches for controller operation, one for automatic or manual, one for signal or flash, and one for signal on or off. A 6 mm (1/4 in.) phone jack receptacle shall be connected to the proper circuits for manual control of any signal interval. The switches shall be protected from water when the door is opened.

 In a cabinet for actuated controllers, the police door shall contain two separate switches, one switch for master power cut-off and one switch to change automatic signal control to flashing control, or vice-versa. The switches shall be protected from water when the door is opened.

2920 The cabinet shall contain one duplex convenience outlet and a switch controlled lamp receptacle. The convenience outlet shall be duplex, three-prong, NEMA Type 5-15R grounding outlet in accordance with NEMA WD-6, with ground-fault circuit interruption as defined by the National Electric Code. These units shall be protected with a 15 amp cartridge fuse wired ahead of the multi-breakers.

2930 The cabinet shall contain a thermostatically controlled ventilating fan and a vent with a commercially classified uniform 25 mm (1 in.) thick filter. The vent size and filter size will be according to the provisions for the type of cabinet. The thermostat shall be manually adjustable from 21E to 38EC (70E to 100EF). The fan shall be mounted internally at the top and toward the front of the cabinet to exhaust out the front top lip of the controller. The fan shall be rated at a minimum of 2.83 m³ (100 ft³) per minute. The thermostat shall be located within 150 mm (6 in.) of the fan.

The cabinet shall contain a surge arrestor. The surge arrestor shall be wired behind the multi-breaker, in parallel with the 35 amp circuit breaker signal buss and in series with the 10 amp circuit breaker for the solid state electronic equipment such as controller, conflict monitor and detectors. The surge arrestor shall have a maximum clamp voltage of 350 volts at a peak current of 20,000 amps for a minimum of 20 occurrences. The surge arrestor will operate between -34EC to 74EC (-30EF to +165EF). The dimensions of the unit shall not exceed 80 mm (3.25 in.) wide by 150 mm (6 in.) long by 64 mm (2.5 in.) deep.

2940 Each inductive device, including the fan, shall have a separate power surge protection.

The terminals for AC + and - input to the cabinet shall be capable of accepting a No. 6 wire.

Test inputs A and B shall not be used for any purpose that will prevent interchangeability of controllers manufactured in accordance with these specifications.

2950 The manual flashing switch shall be wired to let the controller operate when the signals are flashing.

The cabinet shall contain a jack mounted type 3 solid state flasher in accordance with NEMA Standards TS1-8 or approved non-repairable unit in accordance with the NEMA Standards TS1-8 electrical and physical dimensions. Repairable flashers shall consist of opto or photo isolated solid state power relays.

2960 Remote flashing shall be provided for all signal circuits. Phases that the controller is to initialize in green, shall be wired to flash yellow. All other phases shall be wired to flash red. Flashing for signal circuits shall be as evenly balanced as possible on the circuits of the flasher controller.

2970 The cabinet shall be wired to activate the pedestrian timing, including load switches and all other necessary components. The pedestrian load switch and the signal load switch shall be a triple signal load switch in accordance with NEMA Standards TS1-5 or approved non-repairable units in accordance with the NEMA Standards TS1-5 electrical and physical dimension requirements. Repairable load switches shall consist of opto or photo isolated solid state power relays. The repairable load switch shall not use a printed circuit board to transmit the 115 volts AC line- in input or signal buss output. Each load switch shall have an indicator for each circuit indicating the status of the input to the load switch.

The load switch signal outputs shall be brought to a separate terminal strip for hook-up of the signal displays. Load switches shall be capable of being programmed for flash, overlap, vehicular, or pedestrian phases with the use of a standard slotted or phillips screw driver or standard nut driver. Programming of the load switches shall be accomplished on the front of the cabinet terminal facilities by installing or removing electrical conductors.

2980 The cabinet for a pretimed secondary controller used in a hardwired interconnect system shall contain a fuse block with a 2 amp fuse for the remote selection of each of the following inputs: Reset 1, Reset 2, Reset 3, Cycle 2, Cycle 3, Split 2, Split 3, and Flash. For an actuated controller, an additional input shall be provided for system or free operation. The fuse block shall have a 150 volt, 10 amp metal oxide varistor on the controller side of the fuse, connected to ground.

2990 The cabinet for a pretimed master controller used in a hardwired interconnect system shall contain a fuse block with a 6 amp fuse for the output selection of each of the following inputs: Reset 1, Reset 2, Reset 3, Cycle 2, Cycle 3, Split 2, Split 3, and Flash. For an actuated controller, an additional output shall be provided for system or free operation. The fuse block shall have a 150 volt, 10 amp metal oxide varistors for each of the output selections, on the controller side of the fuse, connected to ground. The fuse block shall also have a 1.0 K ohms, 30 watt resistor for each of the output selections, on the interconnect side of the fuse, connected to ground.

3000 The cabinet shall contain a main backpanel and supplementary backpanels, as needed. The model number of the main backpanel shall be permanently applied to the front of the backpanel, where it is easily readable, without removing or disconnecting the backpanel. Each controller input and output circuit shall terminate on the main backpanel or on a supplementary backpanel.

 The cabinet shall contain auxiliary control devices such as conflict monitor, vehicle detectors, or other items specified. All terminal facilities and fusing within the cabinet shall be readily accessible for field connection without removing the controller or associated equipment. All equipment and terminals shall be readily accessible for maintenance in the cabinet. The backpanel shall be attached to the cabinet such that access to the backside of the backpanel, for maintenance purposes, shall be accomplished without the use of special tools or removal of auxiliary panels or other cabinet appurtenances.

3010 **b. G Cabinet.** The G cabinet shall be pedestal-mounted or pole-mounted. The bottom of the cabinet shall be reinforced to ensure a secure pedestal mounting. The G cabinet shall have dimensions of 635 mm (25 in.) wide, 965 mm (38 in.) high, 460 mm (18 in.) deep with a tolerance of + 100 mm (4 in.) in all dimensions.

 A cabinet slipfitter shall be used to attach the cabinet to the pedestal. The slipfitter shall fit a 114 mm (4 1/2 in.) outside diameter pipe and shall have a minimum of three set screws equally spaced around the slipfitter.

3020 A vent of adequate size shall be provided. The size of the vent and the filter requirements shall be in accordance with the manufacturer's recommendations.

(1) Cast Aluminum Pedestal Base. A pedestal mounted G cabinet shall have a cast aluminum pedestal base. The cabinet and pedestal base shall be ground mounted on a concrete type A foundation at locations and dimensions as shown on the plans.

3030 The cast aluminum base shall be made of aluminum in accordance with ASTM B 179, alloy ANSI 319.1 or 319.2, or in accordance with ASTM B 26M (ASTM B 26), alloy ANSI 356.0-T6. The square base shall include an access door and anchor bolts with nuts and washers. The base shall be 8630 mm (13 3/8 in.) square and 380 mm (15 in.) in height 32 mm (1 1/4 in.). The weight shall be 10.0 kg " 2.2 kg (22 lbs " 5%).

3040 The base shall be designed to support a 68 kg (150 lb) axial load and 1.0 m² (11 ft²) of signal head area rigidly mounted. For design purposes, the distance from the bottom of the base to the center of the signal head area is 5.5 m (18 ft). In addition to the dead load, the base shall be designed to withstand wind and ice loads on the specified signal head area and on all surfaces of the support, in accordance with the AASHTO Standard Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals. Wind speeds used for design shall be based on a 10 year mean recurrence interval and a wind drag coefficient of 1.2 or as shown in the plans. The base shall contain an access door, which is 200 mm by 210 mm " 6 mm (8 in. by 8 1/4 in. " 1/4 in.) with a stainless steel hex head bolt for attaching the door.

3050 The base shall be attached to a foundation by four anchor bolts, with an anchor bolt circle of 324 mm (12 3/4 in.). Slotted lugs shall be integrally cast into the four corners of the base for attachment of the anchor bolts. The anchor bolts shall be steel in accordance to ASTM A 36M (ASTM A 36). The diameter of the anchor bolt shall be 19 mm (3/4 in.) with a minimum length of 460 mm " 13 mm (18 in. " 1.2 in.), plus 64 to 75 mm (2 1/2 to 3 in.) right angle hook on the unthreaded end. The top 100 mm (4 in.) of the bolt shall be threaded with 10 NC threads. The threads, plus 75 mm (3 in.), shall be coated after fabrication in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C. Each anchor bolt shall be provided with two hex head nuts in accordance with ASTM A 325M (ASTM A 325) and three washers. Two of the washers shall have a minimum 50 mm (2 in.) and maximum 54 mm (2 1/8 in.) outside diameter and be in accordance to ANSI B 27, Type B regular series and one shall be a nominal 19 mm (3/4 in.) series W washer, in accordance with
3060 ASTM F 436M (ASTM F 436).

The cast aluminum pedestal base shall be in accordance with the dimensions and requirements shown in the plans. The casting shall be true to pattern in form and dimensions; free from pouring faults, sponginess, cracks, and blowholes; and free from other defects in positions affecting the strength and value of the intended use for the casting. The base shall not have sharp unfilleted angles or corners. The surface shall have a workmanlike finish.

3070 The door and bolt for the door shall be interchangeable on cast bases from the same manufacturer.

(2) Pedestal Pole. The top of the base shall accommodate a pole having a 114 mm (4 1/2 in.) outside diameter. The threads inside the top of the base shall be 100 mm (4 in.) national standard pipe threads. The pole shall be either a steel pedestal pole or an aluminum pedestal pole.

3080 A steel pedestal pole shall be a seamless schedule 40 carbon steel pipe in accordance with ASTM A 53, grade B. The pole shall have an outside diameter of 114 mm (4 1/2 in.). The pole shall weigh approximately 16 kg/m (10.8 lbs ft). The length of the pole shall be as shown in the plans. The pole shall have full depth national standard pipe threads on one end of the pole. The length of threads shall be 64 mm (2 1/2 in.). The pole shall be galvanized, after threading, in accordance with ASTM A 123. The threads shall be cleaned of all excess galvanizing and protected by a suitable shield.

3090 An aluminum pedestal pole shall be in accordance with ASTM B 241M (ASTM B 241) for seamless aluminum alloy, schedule 40, 6061-T6. The outside diameter of the pole shall be 114 mm (4 1/2 in.). The length of the pole shall be as shown in the plans. The pole shall weigh approximately 5.5 kg/m (3.7 lbs/ft). The pole shall have full depth national standard pipe threads on one end of the pole. The length of threads shall be 64 mm (2 1/2 in.) and protected by a suitable shield. The pole shall have a spun finish.

(3) Pole Cap. A pole cap shall be supplied for the top of the pole if the pole is used for the mounting of pedestrian signal faces or side mounted signal control cabinets. The pole cap shall be either a cast pole cap of aluminum or a pole cap of spun aluminum.

3100 A cast pole cap shall be made of aluminum, in accordance with ASTM B 179, alloy ANSI 319.1 or 319.2. The cap shall fit freely on the 114 mm (4 1/2 in.) outside diameter pole. A set screw using a 19 mm 3/4 in.) No. 12 hex head machine screw shall be supplied to hold the cap on the pole. A standard foundry draft will be allowed on the casting.

A pole cap made from spun aluminum shall be in accordance with ASTM B 209M (ASTM B 209), alloy 1100-0. The cap shall to fit tightly when placed on the end of the pole.

3110 **c. M Cabinet.** The M cabinet shall be ground-mounted on a concrete foundation at locations and dimensions as shown on the plans.

The M cabinet shall have dimensions of 762 mm (30 in.) wide, 1219 mm (48 in.) high, and 406 mm (16 in.) deep with a tolerance of " 50 mm (2 in.) in any or all dimensions.

Anchor bolts shall be steel in accordance with ASTM A 36M (ASTM A 36). Diameter of the bolt shall be 13 mm (1/2 in.) or 16 mm (5/8 in.) and the minimum length shall be 381 mm (15 in.) plus a 75 mm (3 in.) right angle hook on the unthreaded end. The top 150 mm (6 in.) of the bolt shall be threaded with 13 NC threads on 13 mm (1/2 in.) bolts and 11 NC threads on 16 mm (5/8 in.) bolts. The hexagon nut, the flat washer, and the threaded end of the bolt shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

If an interrupter is shelf mounted, a shelf shall be located a minimum of 305 mm (12 in.) from the top of the cabinet but shall have adequate room to easily install or remove the interrupter.

The vent shall have a uniform, 25 mm (1 in.) thick filter which may be of any of the following 3 sizes: 510 by 255 mm (20 by 10 in.); 405 by 255 mm (16 by 10 in.); or 405 by 200 mm (16 by 8 in.).

The cabinet shall contain solid state load switches with incandescent lamp load rating of 1200 watts with nominal 120 volts 60 hertz which meet NEMA Standards TS1-5. Cabinets for pre-timed controllers shall contain a type 6 conflict monitor and cabinets for actuated controllers shall contain a type 12 conflict monitor. Conflict monitors shall be in accordance with NEMA Standards TS1-6. The conflict monitor upon sensing conflicting signal indications or unsatisfactory operating voltage shall transfer the signals to a flashing indication and the controller shall be wired to provide flash transfer if the conflict monitor is removed from service. Each channel of the conflict monitor shall have an indicator to show the channel's on or off status.

A red failure indicator shall be provided, exclusively labeled red failure, and shall be continuously illuminated when red failure has occurred. The conflict monitor shall indicate the channel where red failure occurred by means of the channel indicator.

The phase arrangement of the controller shall coincide with the channel arrangement of the load switches and conflict monitor.

The cabinet shall contain a multi-breaker with one 10 amp circuit breaker to provide overload protection to the controller, conflict monitor, and detectors and one 35 amp circuit breaker to provide overload protection to the signal and flash buss load. When both circuit breakers are in the off or tripped position, the signal output, the conflict monitor, and the controller shall be turned off. The signal shall be capable of operating in the flashing mode with the 10 amp circuit breaker OFF and the 35 amp circuit breaker ON. The controller, the conflict monitor, and the detectors shall be capable of operating with the 10 amp circuit breaker ON and the 35 amp circuit breaker OFF.

3160 Two 1.0 microfarad 600 volts + 10% capacitors shall be installed on the output field terminal strip for left turn phases which are normally phases 1 and 3. One capacitor shall be connected from the green output terminal to AC negative terminal on each phase and the other capacitor shall be connected from the yellow output terminal to AC negative terminal on each phase.

The cabinet shall contain a type 3 solid state flasher in accordance with NEMA Standards TS1, Part 8. The flashing output circuits carrying the signal load shall consist of opto or photo isolated solid state power relays. Programmable flash shall be provided for on the cabinet terminal facilities. No special tools shall be required to program flash. Flashing for even numbered phases shall be placed on one circuit and flashing for odd numbered phases shall be placed on the other circuit.

3170 The cabinet shall contain all terminal blocks, solid state load switch blocks, and harnesses necessary for the operation of the controller. It shall have two adjustable shelves with the first shelf located 380 " 25 mm (15 in. " 1 in.) below the top of the cabinet and the second shelf located 178 mm (7 in.) below the first shelf. The cabinet shall contain 30 spare terminals. The spares shall be in one location and easily accessible in the cabinet. If vehicle detection is required for a controller, the spare terminals may be used for this purpose.

3180 Terminal strips shall be consecutively numbered and shall be in accordance with the schematic diagram. Numbering for terminal strips shall be neat and legible, silk screen type painting. All harnesses shall be of sufficient length to allow for the placement of the controller and conflict monitor at any location within the upper half of the cabinet. The shell of the cabinet connector harnesses shall be grounded. All relays and conflict monitors shall be encased in a protective covering to reduce the potential of electrical shock.

3190 The police panel shall contain two separate switches. One switch for master power cut-off and one switch to change operation from automatic signal control to flashing control, or vice-versa. The switches shall be protected from water when the door is in the open position.

3200 **d. P-1 Cabinet.** The P-1 cabinet shall be ground mounted on a concrete foundation at locations and dimensions as shown on the plans with anchor bolts in accordance with 913.15(a)7c. The P-1 cabinet shall house an 8 phase traffic actuated solid state digital controller and shall have two adjustable shelves with the first shelf located 508 mm (20 in.) below the top of the cabinet and the second located 178 mm (7 in.) below the first shelf. The cabinet shall be 1118 mm (44 in.) wide, 1321 mm (52 in.) high, and 610 mm (24 in.) deep with a tolerance of " 75 mm (3 in.) inches in all dimensions. Maximum exterior dimensions shall be 864 mm (34 in.) deep, 1194 mm (47 in.) wide, and 1600 mm (63 in.) high.

The cabinet shall be in accordance with applicable provisions of 913.15(a)7a and 913.15(a)7c(2). It shall have one type 12 conflict monitor which shall be in accordance with NEMA Standards TS-1, Part 6.

3210 Two 1.0 microfarad 600 volt, 10% capacitors shall be installed on the output field terminal strip for the left turn phases which are normally phases 1, 3, 5, and 7. One capacitor shall be connected from the green output terminal to AC negative terminal on each phase, and the other capacitor shall be connected from the yellow output terminal to AC negative terminal on each phase.

The cabinet shall have a vent with a uniform 25 mm(1 in.) thick filter which may be of any of the following 3 sizes: 405 by 635 mm (16 by 25 in.); 380 by 510 mm (15 by 20 in.); or 405 by 510 mm (16 by 20 in.). It shall contain 40 spare terminals.

3220 **8. Two Circuit Alternating Flasher.** Two circuit alternating flashers shall be solid state.

a. General. The solid state flasher shall periodically interrupt a source of alternating current line power. Solid state shall mean electrical circuits, the active components of which are semi-conductors, to the exclusion of electromechanical devices or tubes.

3230 The flasher shall be a type 3 solid state flasher conforming to Section 8 of the NEMA Standards Publication TS 1-1983. The flasher output circuit carrying the signal load shall consist of opto or photo isolated solid state power relays and shall be hard wired to the flasher connector.

Three schematic diagrams and three descriptive parts lists shall be furnished with each flasher.

Two circuit alternating flashers shall be plug-in design. The flasher design shall not permit the unit to be inserted improperly into the plug-in base. The flasher shall have heavy-duty plugs and jacks capable of handling the rated load current. The rate of flash shall be 50 to 60 flashes per minute.

3240 The flasher shall operate between 95 volts and 135 volts AC 60 Hertz. No degradation of performance shall be experienced in environmental changes from -29EC to 74EC (-20EF to 165EF) and 0 to 90% relative humidity.

b. Cabinet Requirements. The cabinet shall be weatherproof and fabricated from cast aluminum or aluminum sheeting with a minimum thickness of 3.18 mm (0.125 in.). The cabinet door shall be the entire front of the cabinet and shall be hinged on the right or left side of the cabinet. A Corbin No. 2 lock and two No. 2 keys shall be furnished. The lock shall be located near the center of the door on the side opposite the hinge.

3250 Minimum dimensions for the cabinet shall be 305 mm (12 in.) deep, 305 mm (12 in.) wide, and 305 mm (12 in.) high. The maximum dimensions shall be 460 mm (18 in.) deep, 380 mm (15 in.) wide, and 460 mm (18 in.) high.

The cabinet shall have two pole plates for stainless steel band mounting of the cabinet on a pole with a minimum diameter of 100 mm (4 in.) and maximum diameter of 460 mm (18 in.). Two hub plates for 25 mm (1 in.) diameter conduit shall be provided with gaskets, eight bolts at four bolts per plate, nuts, and washers for attaching the hub plates to the cabinet. The cabinet shall be drilled for the mounting of the pole plates or hub plates as shown on the plans.

3260 It shall have a screened vent in the bottom with a minimum size of 1129 mm² (1 3/4 in.²). A fan and thermostat shall be located in the top of the cabinet. The fan shall have separate power surge protection. The thermostat shall be located within 150 mm (6 in.) of the fan and shall be adjustable between 21E and 43EC (70E and 110EF).

3270 The panel in the cabinet shall be capable of being removed and reinstalled with simple hand tools. A 25 amp radio interference filter and surge arrestor in accordance with 913.15(a)7a. wired ahead of a 15 amp circuit breaker shall be mounted on the panel. A terminal block capable of the following electrical connections shall be mounted on the panel.

Circuit 1-	for connection of field signals.
Circuit 2-	for connection of field signals.
AC plus-	can be attached to breaker if circuit breaker can accept a No. 6 wire.
AC minus lug-	capable of accepting a No. 6 wire.
Neutral lug-	capable of accepting a No. 6 wire.
Fan Circuit-	adequately fused separately from circuit breaker with a fuse rating less than 15 amps.

3280

(b) Interconnection Equipment.

1. Hardwire Interconnection.

a. Electro-Mechanical Dial Coordination Unit.

3290 **(1) General.** The coordinating unit shall operate and be compatible with a 2 phase, 4 phase, and 8 phase controller in accordance with 913.15(a)6. It shall function in an interconnect system containing three dial electro-mechanical controllers and actuated controllers and shall contain three background cycles that are programmable in length of time and percentage split.

3300 The dial coordinating unit shall generate a continuous background cycle. With an absence of vehicle actuation, recall operation, or pedestrian actuations, the traffic signal controller shall continue to rest in the coordinated phase. During periods of heavy vehicular demands, the coordinating unit shall not permit transfer of right-of-way to non-coordinated phase or pedestrian until the background cycle is in the predetermined position. When there is insufficient vehicular demand to extend the phase to the force-off limit the unit shall allow an early return to the coordinated phase.

The interface between the coordinating unit and the actuated controller shall provide a yield/force-off type of coordination. The coordinated phase or phases shall yield and the remaining phases shall be forced off. The coordination unit shall operate in a coordinated system with the number of controller phases specified. The interface between the coordinator and the controller shall provide for Max I timing during coordinated operation. During noncoordinated, free run, operation, Max II timings shall be in effect.

3310 The coordinating unit shall operate on 115 volt AC, 60 Hertz. It shall be shelf mounted and enclosed in a case with maximum dimensions of 483 mm (19 in.) wide, 191 mm (7 1/2 in.) high, and 200 mm (8 in.) deep. Three sets of wiring and schematic diagrams, three descriptive parts lists, and two instruction and maintenance manuals shall be furnished with each coordinating unit.

(2) Additional Requirements for Master Locations. A master control unit shall include a dial coordinating unit interrupter and a dial coordinating unit master both compatible and able to function in an interconnected system containing 3 dial electro-mechanical controllers and actuated controllers.

3320 The master control unit shall be capable of the following output selections: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, and coordinating free. The dial coordinating unit master and the dial coordinating unit interrupter shall have the following 5 cycle length gears for each dial:

Dial 1	60-80-90-100-110 sec.
Dial 2 & 3	70-75-85-95-110 sec.

3330 A master control unit shall contain a fuse block with a 6 amp fuse for the output selection of each of the following: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, Split 2, and Split 3. The fuse block shall have 10 amp metal oxide varistors for each of the output selections on the controller side of the fuse, connected to ground. The fuse block shall have 1000 ohm, 30 watt resistors for each of the output selections on the interconnect side of the fuse, connected to ground.

(3) Additional Requirements for Secondary Locations. A secondary control unit shall contain a secondary dial coordinating unit compatible and able to function in an interconnect system containing three dial electro-mechanical and actuated controllers. The location shall be capable of the following input selections from a remote location: Reset 1, Reset 2, Reset 3, Dial 2, Dial 3, Flash, and coordinating free. Two switches within the secondary control unit shall be provided to manually select the following operations and labeled to show which operation is in effect. One switch shall select Dial 1, Dial 2, Dial 3, Time Clock or System. The other switch shall select Coordination or Free Run. secondary dial coordinating unit shall have the same 5 cycle length gears for each of the three dials as required by the master and interrupter dial coordinating units.

(c) Blank.

(d) Signal Head Components.

1. Vehicle Signal Face. Vehicle signal faces shall be as shown on the plans. The components shall be in accordance with the latest standard of the Institute of Transportation Engineers for Adjustable Face Vehicular Traffic Control Signal Heads.

a. General. The signal faces shall be sectional in construction, requiring one section for each lens and furnished in the nominal size of 305 mm (12 in.) Each section of a face shall have a rectangular silhouette when viewed from the front or the rear.

b. Housing, Door, and Visor. The top and bottom of each housing shall have an integral locking ring with 72 serrations to permit rotation of the signal housing in 5 degree increments. Hub openings in the top and bottom of the signal housing shall accommodate standard 38 mm (1 1/2 in.) bracket arms. The thickness of the hub at the top and bottom of the housing shall be a maximum of 25 mm (1 in.) and a minimum of 10 mm (3/8 in.). The 305 mm (12 in.) door shall have two simple locking devices. The door on the hinged side shall be attached with hinge pins. Each lens shall have the standard cap type visor. All screws, latching bolts, locking devices, and hinge pins shall be stainless steel.

c. Lens. The lens shall be made of plastic and shall be in accordance with ASTM D 788, grade 8; ASTM D 702, grade 3; or ASTM D 3935. The index of refraction shall be between 1.48 and 1.59. The lens shall be uniformly colored throughout the body of the material, true to size and form, and free from any streaks, wrinkles, chips, or bubbles. The values of luminous transmission for the signal lens and the limits of chromaticity for the lens colors shall be in accordance with the latest standard of the Institute of Transportation Engineers for Adjustable Face Vehicular Traffic Control Signal Heads. The lens hole with the lens gasket in place shall be of sufficient size to accommodate a 305 mm (12 in.) diameter lens.

d. Reflector Assembly. The reflector shall be made of Specular Alzak Aluminum. The reflector assembly shall be designed so that it is pivoted and can be swung out of the housing and easily removed without the use of tools. A neoprene gasket shall be provided between and completely around the reflector and the reflector frame and shall be reusable. The reflector frame shall be aluminum or plastic.

3390 **e. Lamp Receptacle and Wiring.** The lamp receptacle shall be fixed focus type, positioning the lamp filament at the correct focal point with respect to the reflector. The assembly shall be designed so the lamp socket can be rotated through 360 degrees into positions of adjustment for proper positioning of the lamp filament after relamping. The lamp socket shall be equipped with color coded wire either red, yellow, or green depending upon the lens color of the section. The socket wires shall be a minimum of 660 mm (26 in.) long, fixture wire No. 18 AWG or larger, 600 volts, with insulation designed to withstand 105EC (221EF). The conductor size, insulation type letter designation, and temperature rating shall be marked on the insulation or a material certification of compliance shall accompany each signal head combination. The wiring leads shall be terminated with screw spade lug type or female type connectors for ease of connection to the terminal block. The socket shall be equipped with a gasket to insure a dust tight fit between the socket and reflector.

3400 **f. Section Coupling.** Any method to connect two or more sections together may be used, if the following requirements are met:

- (1) Two or more sections, when jointed together, shall maintain structural integrity when loaded to Institute of Transportation Engineers Standards.
- (2) The opening between joined sections shall accommodate two 13 mm (1/2 in.) cables.
- (3) The maximum length of bolts used to connect sections together shall be 100 mm (4 in.).

3410 Nuts, bolts, or lock washers shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and be in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C.

3420 **g. Terminal Block.** The yellow section of the 3 section signal head shall be equipped with a 5 position terminal block for termination of field wiring. Each section shall have provisions for addition of an 8 position terminal block or two 5 position terminal blocks or one 5 position and one 3 position terminal block. The terminal block shall have a minimum spacing between screw connections of 13 mm (1/2 in.). The height of the insulating ridge between screw connections shall be a minimum of 15 mm (19/32 in.) from the base of the terminal blocks.

h. Material Requirements.

3430 **(1) Polycarbonate Signal Head.** The housing, door, and visor of the section shall be made of ultraviolet and heat stabilized polycarbonate. The color shall be permanently molded into the components except the inside surface of the visor shall be painted non-reflecting flat black. The color shall be yellow in accordance with 909.02(b)4.

3440 **(2) Die-Cast Aluminum Signal Head.** The housing, door, and visor of the section shall be made of a die-cast, corrosion resistant, copper free, non-ferrous metal which shall be in accordance with ASTM B 85. All surfaces of the housing, doors, and visor shall receive a prime coat of zinc chromate paint in accordance with 909.02(a) or shall be anodized with a chromate aluminum oxide coating process. The finish shall be highway yellow enamel, two coats, oven baked and in accordance with 909.02(b) except the inside surface of the visor shall be painted non-reflecting flat black.

i. Certification. A material certification in accordance with the applicable provisions of 916 shall accompany each order certifying that a signal head from a normal production run within the past 12 months, passed the Institute of Transportation Engineers criteria for breaking strength and deflection. Deflection testing is not required in the certification for polycarbonate signal heads.

3450 **2. Pedestrian Signal Head.** A pedestrian signal shall be one section and rectangular in shape. The dimensions of each side may vary from 460 to 485 mm (18 to 19 in.), including the visor and the hinges. The signal shall contain two figures with two different colored messages. The left figure shall transmit an upraised hand symbol message, and the right figure shall transmit a walking person symbol message. The pedestrian signal shall be in accordance with the standard of the Institute of Transportation Engineers for Pedestrian Traffic Control Signal Indications.

3460 **a. Housing, Door, and Visor.** The housing shall be equipped with mounting device hardware, such as clamshell, and round openings at top and bottom for mounting with brackets made of iron pipe standard, to fit the 38 mm (1 1/2 in.) pipe. The openings shall have a common vertical centerline through the housing to permit 360 degrees rotation after it is mounted. The openings shall have a serrated ring which permits locking of the housing in 5 degree increments throughout the entire 360 degrees of rotation. The brackets or the clamshell shall serve as the electrical conduit for the pedestrian signal. The housing shall be made of diecast, corrosion resistant, copper free, non-ferrous metal which shall be in accordance with ASTM B 85.

3470 The door on the front of the housing may be hinged from any side. The door shall be gasketed to maintain a weather-tight enclosure when secured to the housing. The door and the visor shall be made of the same material as the housing or of polycarbonate. All materials shall be clean, smooth, and free from flaws, cracks, blowholes, or other imperfections.

The exterior of the housing shall be Federal yellow in color. The polycarbonate components shall be black in color impregnated throughout. The metal components shall be painted with enamel in accordance with 909.02(b).

3480 Each signal shall be provided with a visor. The visor shall consist of a minimum of 20 horizontal and 20 diagonal equally spaced louvers. Every other formed louver shall be reversed to provide diamond shaped cells each having a minimum area of 650 mm² (1 in.²). The louvers shall be made of impregnated black polycarbonate plastic processed with a flat finish on both sides, to eliminate sun phantom. The door and visor assembly shall be attached to the housing by means of stainless steel screws and nuts.

b. Optical Unit. The optical unit shall consist of the redirecting lens, the lamp, a reflector, a filter, and other optical elements necessary for proper operation. The optical unit shall be designed to minimize the return of the outside light rays entering the unit, such as sun phantom. The optical unit shall be designed and assembled so that no light escapes from one message unit to the other.

3490 The values of luminous transmission for pedestrian signal lenses and the limits of chromaticity for pedestrian signal colors shall be in accordance with the standard of the Institute of Transportation Engineers for Pedestrian Traffic Control Signal Indications.

3500 **c. Lens.** The lens shall be made of plastic. The lens shall be in accordance with ASTM D 788, grade 8; ASTM D 702, grade 3; or ASTM D 3935. However, the index of refraction shall be between 1.48 and 1.53. As required by the type of pedestrian signal, the lens shall be uniformly clear or colored throughout the body of the material, true to size and form and free from any streaks, wrinkles, chips, or bubbles.

3510 **d. Message.** When illuminated, the upraised hand symbol shall be in Portland Orange on the left surface of the signal indications. The walking person symbol shall appear in white on the right surface of the signal indication when illuminated. The upraised hand and walking person symbols shall each be a minimum of 280 mm (11 in.) in height. The width of the upraised hand symbol shall be a minimum of 178 mm (7 in.). The width of the walking person symbol shall be a minimum of 150 mm (6 in.). Message configuration, color, and size shall be in accordance with the standard of the Institute of Traffic Engineers for Pedestrian Traffic Control Signal Indications.

e. Reflector Assembly. The reflector shall be a double parabolic type, made of textured polycarbonate plastic sheet coated with aluminum, or made of specular Alzak Aluminum with bead or flange on the outer edge to stiffen the reflector and ensure the true shape. The reflecting surface shall be free of flaws, scratches, defacements, or mechanical distortion.

3520 The 2 sections of the reflector shall be divided by a full depth divider which properly mates with the message lens to effectively prevent light spillage from one section to the other.

f. Light Distribution. The illuminated signal shall be uniformly illuminated over the entire message surface without shadows when viewed from usual angles encountered in service. The upraised hand and walking person symbols shall not appear to be illuminated portions of the lens. When not illuminated, the upraised hand and walking person symbols shall not appear to be illuminated by external light sources when viewed from the far end of the crosswalk. The pedestrian indication shall be visible to the pedestrian at all times at all distances from 3 m (10 ft) to the full width of the street to be crossed.

3530 **g. Electrical.** The signal shall be equipped with a lamp and a socket for each of the 2 sections of the double parabolic reflector. The lamp receptacle shall be of heat resisting material. The lamp receptacle shall be provided with a grip to prevent the receptacle from working loose due to vibration. Each lamp shall be traffic signal lamp type A 21. The metal portion of the lamp receptacle shall be compatible with brass or copper.

3540 Each pedestrian signal shall be completely wired internally, and ready for connection of the field wiring. A suitable terminal block for connection of the internal wiring and the incoming field wires to the pedestrian signal head shall be provided in the signal housing.

The light source shall be designed and constructed so that if an electrical or mechanical failure occurs, the upraised hand and walking person symbols shall also remain dark.

3550 **3. Disconnect Hanger Junction Box.** Traffic signal disconnect hanger junction boxes shall consist of a span hanger, a balance adjuster, a disconnect hanger clevis, and a housing with a hinged door with a positive latching device. The span hanger, balance adjuster, and all related hardware shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. The housing shall be made of a die-cast, corrosion resistant, copper free, nonferrous metal which shall be in accordance with ASTM B 85. The balance adjuster fitting shall be made of ferrous or non-ferrous metal. When made of ferrous metal it shall be galvanized in accordance with the requirements for the components and related hardware as set out above.

3560 The disconnect hanger shall be designed so that the maximum allowable space or play between the span hanger and the eye-bolt of the balance adjuster and between the balance adjuster and the disconnect hanger clevis, at points where they are attached to each other by rivet pins or hex head bolts and nuts with lock washers, shall be 1.6 mm (0.062 in.). The span hanger bolt where the eye-bolt or the balance adjuster is attached shall be 16 mm (5/8 in.) diameter.

3570 When serrated locking rings are not integrally cast in the components, the component and locking ring shall be designed so that when the locking ring is placed flush against the component, the component and locking ring shall not rotate or slide when torque is applied. The serrated components shall have 72 serrations to permit rotation of the disconnect hanger clevis, hub plate, or signal head in five degree increments. There shall be no thread in contact with a wearing surface. Locking rings shall have a minimum thickness of 4.8 mm (3/16 in.) and a maximum thickness of 6.4 mm (1/4 in.) from the base of the ring to the serration peaks. The inside diameter shall be 50 mm (2 in.) and the outside diameter shall be 73 mm (2 7/8 in.).

3580 The terminal block shall have an 18 point terminal block permanently engraved or etched with sequential numbers indicating the circuits. The terminal block shall not have a method of connection which allows a screw point to damage wires when the wires are securely connected. Each point of connection shall accommodate a minimum of four No. 14 gauge (2.0 mm) wires.

The disconnect hanger shall have two side entrance holes on opposite sides capable of receiving a 38 mm (1 1/2 in.) plastic or rubber insert to reduce water infiltration. It shall be capable of supporting signal faces in the ambient temperature range of -35EC to 49EC (-35EF to 49EF) without failure.

3590 The balance adjuster shall have hex head bolts, lock washers, and nuts for securing the main body of the balance adjuster firmly onto and around the eye-bolt to prevent any twisting or turning of the head suspended below it. The span hanger shall have two J-bolts, lock washers, and hex head nuts adequate in size to securely fasten the hanger to a messenger cable up to 13 mm (1/2 in.) in diameter.

A type C certification in accordance with 916 shall be provided.

4. Signal Bulbs. The minimum design requirements for light bulbs to be used in a traffic signal face shall be in accordance with the Institute of Transportation Engineers standard for traffic signal bulbs and as follows:

- a. Bulbs shall be 67 watt, 116 watt, or 150 watt for different kinds of indications, as specified below.

3600

INDICATION

WATTAGE

230 mm (9 in.) pedestrian	67
305 mm (12 in.) and 455 mm (18 in.) pedestrian	116
200 mm (8 in.) red, yellow and green	67
305 mm (12 in.) red	150
305 mm (12 in.) yellow and green	116
305 mm (12 in.) yellow and green arrows	150
optically programmed heads	150

3610

- b. All bulbs shall have medium size, brass bases.
- c. Bulbs shall be designed for use in a horizontal position or a base-down position.
- d. The light center length shall be 62 mm (2 7/16 in.) for 67 watt bulbs and 75 mm (3 in.) for 116 watt and 150 watt bulbs.
- e. The filament shall be C9 design with a minimum of seven supports. The 2 voltage supply leads may be counted as two of the seven supports.

3620

- f. The maximum, overall bulb length for 67 watt and 116 watt bulbs shall be 111 mm (4 3/8 in.) and for 150 watt bulbs shall be 120 mm (4 3/4 in.).
- g. All bulbs shall be clear and shall be 130 volt.
- h. The 150 watt bulb shall be P25 or A21 size and shape.

3630

- i. The 67 watt and 116 watt bulbs shall be A21 size and shape.
- j. All bulbs shall have 6000 h minimum burning life.

5. Free Swinging Signal Support Assemblies. The maximum allowable space or play between the hanger assembly and the eyebolt of the balance adjuster and between the balance adjuster and the weatherhead clevis, at points where they are attached to each other by rivet pins or hex head bolts and nuts with lock washers, shall be 1.6 mm (0.062 in.). No bushings or shims will be allowed in this assembly.

3640

The balance adjuster shall consist of a hex head bolt, a lock washer, and nuts for securing the main body of the balance adjuster onto and around the threads of the eye-bolt to prevent any twisting or turning of the adjuster.

3650 The span hanger, balance adjuster, weatherhead, and all related hardware shall be made of a non-corrosive metal or shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. The weatherhead shall have a minimum of 64 mm (2 1/2 in.) of exposed threads. The weatherhead shall have two set screws to fasten the nipple to the weatherhead. If the weatherhead and threaded pipe has a slipin connection, the locking device shall be a double nut assembly. If the weatherhead and threaded pipe has a screw-in connection, the locking device shall be a double set screw assembly.

3660 The span hanger shall be furnished with two each of J-bolts, lock washers, and hex head nuts. The J-bolt shall be a minimum of 6.4 mm (1/4 in.) diameter and shall have sufficient threads to be able to secure the hanger to a 6.4 mm (1/4 in.) or a 13 mm (1/2 in.) messenger cable. The multiple pipe arm assembly shall consist of a span hanger assembly, a balance adjuster, a signal weatherhead, a 2, 3, or 4 way pipe arm, 38 mm (1 1/2 in.) pipe, a lower arm assembly, and all related hardware necessary for a complete assembly.

The 2, 3, or 4 way pipe arms shall have a minimum of 50 mm (2 in.) of exposed thread. Each arm of the pipe arm shall be furnished with two 72 serration locking rings. One locking ring shall have a 75 mm (3 in.) outside diameter and one locking ring shall have a 60 mm (2 3/8 in.) outside diameter.

	ASSEMBLY	MAXIMUM ALLOWABLE WEIGHT
3670	2 Way	8.6 kg (19 lbs)
	3 Way	11.3 kg (25 lbs)
	4 Way	12.7 kg (28 lbs)

6. Mid-Mast Arm Mount Signal Bracket. The bracket shall permit the following 4 adjustments:

- 3680
- a. rotational adjustment about bracket axis;
 - b. vertical adjustment;
 - c. rotational adjustment about mast arm; and
 - d. rotational adjustment right and left from vertical plane

The bracket shall be fastened to the supporting arm or structure with stainless steel bands. The bracket shall adjust to fit all sizes of round, octagonal, elliptical, or other shape structure without special tools or equipment.

3690 The bracket shall attach to the signal by clamping the signal head both top and bottom and shall be designed to accommodate the specified signal configuration. Each bracket shall be complete with all necessary hardware to attach the traffic signal to the bracket and the bracket to the support.

All electrical wiring shall be concealed within the bracket, except that which runs from the bracket to the mast arm.

3700 Upper and lower arms shall be cast from aluminum in accordance with ASTM B 26M (ASTM B 26), alloy 713.0-T5 or 356.0-T6. The vertical support tube shall be extruded from aluminum in accordance with to ASTM B 241M (ASTM B 241), alloy 6063-T6 or 6061-T6, and the strapping to attach the bracket to the arm shall be stainless steel. All steel or malleable iron parts shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153.

7. Pedestal Mounted Control Cabinets or Pedestrian Signal Heads. The pedestal base used for mounting pedestrian signal heads or control cabinets shall be in accordance with 913.15(a)7b(1). The length of the pedestal pole shall be as shown in the plans.

3710 **(e) Signal Support.**

1. Steel Strain Pole. The steel strain pole shall be an anchor base type pole and shall include a handhole and a pole top or cap. The poles shall be furnished in lengths specified.

The pole shall have a reinforced handhole within 460 mm (18 in.) of the base. The minimum size shall be 130 mm (5 in.) by 200 mm (8 in.) with a cover and latching device. The pole shall have a top or cap with a set screw that can be removed with small hand tools.

3720 The pole material shall be in accordance with ASTM A 595 or A 572 with a minimum yield strength of 345 kPa (50,000 psi). The pole shall be galvanized after fabrication in accordance with ASTM A 123.

3730 All hardware, handhole cover and latching device, band type steel polebands, steel bolts, nuts, and washers shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to the coating thickness, adherence, and quality requirements of ASTM A 153. All nuts and bolts, except anchor bolts, shall be in accordance with ASTM A 307. If a cast pole top or cap is used it shall be in accordance with to ASTM A 126 and shall be galvanized with a minimum coating of 0.610 kg/m² (2 oz/ft²).

The polebands shall fit the pole as planned. The wire rope shall not be in contact with any 90 degrees edges or with any threads on the band. The pole band material shall be in accordance with to ASTM A 572M (ASTM A 572), grade 50; ASTM A 606; or ASTM A 36M (ASTM A 36) with minimum yield of 345 kPa (50,000 psi). The minimum width of the bands shall be 75 mm (3 in.) and the bands shall be capable of supporting the pole design load. Each half of the band shall be stamped with the corresponding size number.

3740

All welding shall be in accordance with 711.32. Welds shall generate the full strength of the shaft. Only longitudinal continuous welding shall be permitted on the pole shaft. Contacting joint surfaces shall be thoroughly cleaned before fabrication then completely sealed by means of welding. Shop drawings shall be submitted in accordance with 913.15(e)3i.

The pipe coupling for the weatherhead and base plate shall be installed prior to galvanizing. The threads shall be cleaned of all excess galvanizing. An internal J-hook shall be installed near the top of the pole for wire support.

3750

a. Maximum Load 35.6 kN (8000 lbs). The steel strain pole shall be capable of supporting an 35.6 kN (8000 lbs) load applied horizontally 460 mm (18 in.) below the top of the pole with a maximum allowable deflection of 4.1 mm (0.16 in.) per 445 N (100 lbs) of load. The pole shall be tapered 12 mm per meter (0.14 in. per foot) of length.

A one piece base plate shall be secured to the base of the pole and shall develop the full strength of the pole. The base plate material shall be in accordance with ASTM A 36M (ASTM A 36), A 572M (A 572), or A 588M (A 588). The base plate shall have four holes of adequate size to accommodate 57 mm (2 1/4 in.) anchor bolts. The bolt circle shall have a 560 mm (22 in.) diameter and bolt square of 394 mm (15 1/2 in.).

3760

Four high strength steel anchor bolts, 57 mm (2 1/4 in.) diameter and 2,400 mm (96 in.) long, including the hook, shall be furnished with each pole. Each bolt shall have two hex nuts and two washers in accordance with ASTM A 307, grade A. The anchor bolt material shall be in accordance with ASTM A 576 or ASTM A 675M (ASTM A 675) with a minimum yield strength of 379 kPa (55,000 psi) or ASTM A 36M (ASTM A 36), special quality, modified to 379 kPa (55,000 psi) or approved equal. The threaded end of the anchor bolt shall have 305 mm (12 in.) of 4 1/2 NC threads and shall be galvanized the length of the threads, plus 75 mm (3 in.). The threaded end shall be coated after fabrication in accordance with ASTM A 153 or be mechanically galvanized and be in accordance with the coating thickness, adherence, and quality requirements of ASTM A 153, class C. The unthreaded end of the anchor bolt shall have a standard L bend for a distance of 230 mm (9 in.) from the centerline of the anchor bolt to the end of the L. In lieu of the standard bend a steel plate 2900 mm² (4 1/2 in.²) and 32 mm (1 1/4 in.) thick may be welded to the embedded end of the anchor bolt.

3770

3780 **2. Wood Strain Pole.** Wood strain poles shall be made from southern yellow pine and shall be in accordance with the current ANSI Specifications and Dimensions for Wood Poles No. 05.1. They shall be of the length and class specified.

All poles shall be full length pressure treated by the full cell process in accordance with current specifications as set forth in the AWPAs Standards C1 and C4, using preservative as outlined in standard P5 and set forth in 911.02(g)2.

Treatment, handling, and storage methods shall be in accordance with the current AWPAs Standards.

3790 **3. Signal Cantilever Structures.**

a. General. A signal cantilever structure shall be designed in accordance with the latest AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, except where modified herein.

Where the manufacturer has wind tunnel test data, he may use drag coefficients based on actual tests. Otherwise, the manufacturer shall use the drag coefficients in Table 1.2.5c.

3800 **b. Signal Support.** The traffic signal pole and mast arm shall be designed to support the loads in accordance with the plans in an 129 km/h (80 mph) wind with gusts to 167 km/h (104 mph). Loading shall assume diecast aluminum heads.

3810 The traffic signal pole and mast arm shall be designed to provide a 5.3 m (17 ft) minimum clearance at all signals. Clearance shall be the vertical distance from the lowest point of the signal combination to a horizontal plane 75 mm (3 in.) below the base of the mast arm pole or from the lowest point of the signal combination to the pavement surface below the signal combination, which ever governs. Adjustment of the clearance at the installation site shall be by raising or lowering the mast arm along the upper length of the pole. After the pole is anchored to the foundation, the pole design shall permit the mast arm to be rotated 90 degrees in either direction and secured. The cable inlet shall not be obstructed when a field rotation or vertical adjustment of the mast arm is made.

There shall be no threads in the wearing surface plane at the point of connection between the clevis clamp and the signal face assembly. The clevis clamp shall have a 18 mm (11/16 in.) diameter bolt hole to receive the signal face assembly.

3820 **c. Combination Signal-Luminaire Support.** All requirements for a signal support shall apply to a combination signal-luminaire support.

The minimum design load of the luminaire shall be 24 kg (53 lbs) with a projected surface area subject to wind loading of 0.223 m² (2.4 ft²). If heavier or larger luminaires are used, their actual values shall be used. The required luminaire mounting height shall be in accordance with the plans. Mounting height shall be defined as the vertical distance from the lowest point of the luminaire to the horizontal plane which passes through the base of the pole.

3830 The maximum percentage of allowable stress shall be 80% of the AASHTO Standard Specifications for Group I loads. Vibration dampers shall be furnished as recommended by the manufacturer.

d. Pole Requirements.

3840 **(1) General.** The pole shall be a round or multi-sided tapered tube, except the upper 1.2 to 1.8 m (4 to 6 ft) of a signal support pole may be nontapered. The signal support pole shall have a reinforced handhole 100 mm (4 in.) by 150 mm (6 in.) minimum complete with cover and latching device located 460 mm (18 in.) above the base. A 13 mm (1/2 in.) 13 NC threaded grounding nut or approved equivalent shall be provided and be accessible through the handhole. The pole cap shall be secured in place with set screws. The combination signal-luminaire pole shall have a reinforced handhole 100 mm (4 in.) by 200 mm (8 in.) minimum complete with cover and latching device, located 460 mm (18 in.) above the base. The combination signal-luminaire pole shall be provided with a removable pole cap and integral wire support hook for the luminaire electrical cable. The cable shall be attached to the hook by a service drop clamp. A wiring hole with a 25 mm (1 in.) to 38 mm (1 1/2 in.) inside diameter grommet shall be provided where the luminaire mast arm attaches to the pole.

3850 **(2) Deflection.** The maximum allowable horizontal deflection of the pole under maximum loading conditions shall not exceed a deflection angle of one degree 10 min from the vertical axis of the pole for any 305 mm (1 ft) section of the pole along the entire length of the pole.

3860 **(3) Materials.** The signal pole and the combination signal-luminaire pole shall be steel or aluminum. Steel poles shall be in accordance with ASTM A 595 or A 572 with a minimum yield strength of 345 kPa (50,000 lbs) and shall be galvanized in accordance with ASTM A 123. Aluminum poles shall be in accordance with ASTM B 221M (ASTM B 221) alloy 6063-T6 or 6005-T5, or ASTM B 241M (ASTM B 241), alloy 6063-T6.

(4) Hardware. All hardware for steel poles except bolts for the mast arm clamps and anchor bolts shall be in accordance with ASTM A 307 and shall be galvanized in accordance with ASTM A 153 or be mechanically galvanized and conform to coating thickness, adherence, and quality requirements of ASTM A 153. A cast pole cap shall be in accordance with ASTM A 126 and shall be galvanized with a minimum coating of 0.610 kg/m² (2 oz/ft²).

3870 All hardware for aluminum poles shall be stainless steel in accordance with
ASTM A 276, type 304 or type 305.

3880 **(5) Anchor Base.** A one piece anchor base shall be secured to the lower end of the pole and shall develop the full strength of the pole. The base shall be provided with 4 holes of adequate size to accommodate 32 mm (1 1/4 in.) anchor bolts equally spaced on a bolt circle of 380 mm (15 in.) diameter and shall have four tapped holes for attaching the bolt covers. Four removable bolt covers shall be provided with each base and each cover shall attach to the upright portion of the body of the base by means of one hex head cap screw. The steel for the anchor base shall be in accordance with ASTM A 36M (ASTM A 36), A 572M (A 572), or A 588M (ASTM A 488). Aluminum for the anchor base shall be in accordance with ASTM B 26, alloy 356.0-T6 or 356.0-T7 or ASTM B 209, alloy 6061-T6.

e. Arm Requirements.

3890 **(1) Signal Cantilever Arm.** A signal cantilever arm shall be attached to the pole by circular clamps. One-half of the clamp shall be welded to the cantilever arm. The single member arm or the upper tapered member of the truss style arm shall have a cable inlet adjacent to the clamp complete with grommet. The cable inlet shall be a 44 mm (1 3/4 in.) diameter hole with a 38 mm (1 1/2 in.) inside diameter rubber grommet. The 6.1, 7.6 and 9.2 m (20, 25, and 30 ft) cantilever arms shall have one intermediate cable inlet with grommet located 3.7 m (12 ft) from the free end of the arm. The 10.7 and 12.2 m (35 and 40 ft) cantilever arm shall have two intermediate cable inlets with grommets located 3.6 m (12 ft) and 7.3 m (24 ft) respectively from the free end of the arm. The intermediate cable inlet shall be 25 mm (1 in.) diameter hole with 19 mm (3/4 in.) inside diameter rubber grommet.

3900 The maximum rise of the single member arm shall be 13 mm (1/2 in.) per 305 mm (1 ft) of arm after loading. The maximum rise of the truss style arm shall be as set out in the table. The rise shall be measured vertically from the centerline of the free end of the truss to a plane through the centerline of the upper arm bracket after loading.

Mast Arm Length m (ft)	Total Rise m (ft - in.)	Tolerance mm (in.)
3.7 - 6.1 (12 - 20)	1.2 (4-0)	"25 ("1)
7.6 (25)	1.3 (4-3)	"25 ("1)
9.2 - 12.2 (30 - 40)	1.4 (4-7)	" 25 ("1)

The end signals on the truss style arms shall be suspended and the intermediate signals shall be rigidly attached. All signals on the single member arms shall be rigidly attached as shown on the plans. The cantilever arms shall be used as an enclosed raceway for wiring and shall be free of burrs and rough edges.

3910 Both parts of the clamp for the single member arms shall be stamped with the arm length prior to galvanizing.

(2) Luminaire Mast Arm for Combination Support. The luminaire mast arm shall be in accordance with 913.11(a)1.

(3) Materials. The signal mast arm shall be of the same material as the pole. The luminaire mast arm shall be of the same material as the pole except that a truss type arm shall be in accordance with 913.11(a). Bolts for the mast arm clamp shall be stainless steel in accordance with ASTM A 276, type 304 or 305.

3920 **f. Anchor Bolts.** Four steel anchor bolts, each fitted with two hex nuts
and two flat washers, shall be furnished with each pole. The anchor bolt shall be one
32 mm (1 1/4 in.) diameter with a minimum of 254 mm (10 in.) of 7 NC threads on the
upper end. The threads, nuts, and washers shall be galvanized in accordance with
ASTM A 153 or be mechanically galvanized and conform to the coating thickness,
adherence, and quality requirements of ASTM A 153. The anchor bolt shall be
1220 mm (48 in.) long with a 100 mm (4 in.) right angle bend on the lower end or a
square steel washer, 150 mm by 150 mm by 13 mm (6 in. by 6 in. by 1/2 in.), with a
hex nut welded onto the lower end. The steel for the bolt shall be in accordance with
ASTM A 576 or ASTM A 675M (ASTM A 675), with a minimum yield strength of
3930 379 kPa (55,000 psi), or ASTM A 36M (ASTM A 36), special quality, modified to
379 kPa (55,000 psi) or approved equal.

g. Finish. All steel material shall be fully galvanized. Galvanizing shall take place after all welding is accomplished. Aluminum poles shall be provided with a satin finish accomplished by mechanical rotary grinding and aluminum mast arms shall be provided with a satin etched finish.

h. Certification. Unless otherwise specified, all materials covered herein shall be covered by a type C certification in accordance with 915.

3940 **i. Shop Drawings.** Five sets of shop drawings and a set of design
calculations shall be submitted to the Division of Design for approval. A copy of the
transmittal letter shall be sent to the Engineer. The approved drawings will be
distributed by the Division of Design.

3950 **4. Downguys, Anchors, Rods, and Guards.** Pole anchors shall be 8 way
expanding with a minimum area of 87,100 mm² (135 in.²) when expanded or a 250 mm
(10 in.) diameter screw anchor. They shall have a minimum holding strength of
44.5 kN (10,000 lb). They shall be painted and in accordance with ASTM A 569M
(ASTM A 569). Anchor rods for expanded anchors shall be 19 mm (3/4 in.) diameter
steel and for screw anchors shall be 32 mm (1 1/4 in.) diameter steel, 2.4 m (8 ft) long,
in accordance with ASTM A 659M (ASTM A 659), and be galvanized in accordance
with ASTM A 153.

Guy guards shall be made of 18 gauge galvanized steel, polyethylene, polyvinylchloride, or melamine phenolic, and shall be 2.1 m (7 ft) long. The steel guy guard shall have a tight gripping, non-scarring hook for quick attachment to the guy wire. The bottom shall have a clamp that fits over the anchor rod and securely grips by tightening the bolt. Steel guy guards shall be in accordance with ASTM A 659M (ASTM A 659). The nonmetallic guy guard shall be a helical pigtail which shall resist upward movement, a lock strap to secure the lower end, and a guy guard sleeve. Non-metallic guy guards shall be gray or yellow.

(f) Messenger Cable.

1. Messenger Cable. Messenger cable shall be zinc-coated steel wire strand, contain seven wires, and have a nominal diameter of 10 mm (3/8 in.). The cable shall be in accordance with ASTM A 475, Siemens-Martin Grade.

2. Span, Catenary, and Downguy Cable. Span, catenary, and downguy cable, shall be aircraft cable for non-aircraft use, and shall be 10 mm (3/8 in.) nominal diameter, made of stainless steel wire, and consist of seven, 19 wire flexible steel strands. The 10 mm (3/8 in.) cable shall have a minimum breaking strength of 53.4 kN (12,000 lb). It shall be in accordance with Military Specifications MIL-W-1511.

3. Tether and Support Cable. Tether and support cable shall be aircraft cable, for non-aircraft use, and shall be 3 mm (1/8 in.) nominal diameter, made of stainless steel wire, and consist of seven, 7-wire flexible steel strands. The 3 mm (1/8 in.) cable shall have a minimum breaking strength of 7560 N (1700 lbs). It shall be in accordance with Military Specifications MIL-W-1511.

4. Cable Hardware.

a. Messenger Hangers. Messenger hangers shall be either a three bolt clamp or a 10 mm (3/8 in.) by 44 mm (1 3/4 in.) steel hanger with a 90 degree bend extending from the pole 95 mm (3 3/4 in.). The hanger shall have a curved groove and clamp capable of receiving a 8 mm to 13 mm (5/16 in. to 1/2 in.) cable.

The messenger shall be clamped by two 13 mm 1/2 in.) high carbon steel bolts. The angle hanger shall be mounted with a 16 mm (5/8 in.) through bolt and a 13 mm (1/2 in.) lag screw. The three bolt clamp shall be mounted with a 16 mm (5/8 in.) through bolt. The angle hanger shall be in accordance with ASTM A 575. The bolts shall be in accordance with NEMA PH 23.

b. Cable Ring. Cable rings shall be galvanized steel in accordance with IMSA 51-1.

c. Clamps. Clamps shall be made of 10 mm (3/8 in.) steel and in accordance with ASTM A 575.

4000 Two bolt clamps shall be a minimum of 95 mm (3 3/4 in.) long and 32 mm (1 1/4 in.) wide with two 13 mm (1/2 in.) bolts which shall clamp cable of 3 to 13 mm (1/8 to 1/2 in.) diameter.

Three bolt clamps shall be a minimum of 150 mm (6 in.) long and 42 mm (1 5/8 in.) wide with three 16 mm (5/8 in.) bolts which shall clamp cable of 8 mm to 13 mm (5/16 to 1/2 in.) diameter.

4010 The bolt heads shall be large enough to provide maximum clamping area and shall have oval shoulders to prevent the bolts from turning while tightening. The bolts shall be in accordance with NEMA PH 23.

d. Servi-Sleeves. Servi-sleeves shall be 32 mm to 57 mm (1 1/4 to 2 1/4 in.) in length and shall hold the size of the cable specified. The sleeves shall be in accordance with ASTM A 659M (ASTM A 659).

4020 **e. Straight Eye-Bolts.** Straight eye-bolts shall be 19 mm (3/4 in.) diameter drop forged steel, a minimum of 356 mm (14 in.) long, and have 150 mm (6 in.) of thread. The steel washers shall be 57 mm (2 1/4 in.) by 57 mm (2 1/4 in.) by 5 mm (3/16 in.) in size with 21 mm (13/16 in.) hole in the center. All parts shall be in accordance with ASTM A 575 and shall be galvanized in accordance with ASTM A 123.

f. Hub-Eyes. Hub-eyes shall be made of drop forged steel and in accordance with ASTM A 575. They shall receive a 19 mm (3/4 in.) mounting bolt and have a full rounded thimble eye for protection of the guy cable.

5. Signal Cable.

4030 **a. Hook-up Wire.** Signal hook-up wire shall be stranded one conductor wire, type THW 7 strand No. 14 AWG, with a thermoplastic sheath 1.19 mm (3/64 in.) thick and a 600 volt rating. Insulation shall be color coded, as required, and labeled with gauge, voltage rating, and insulation type.

b. Signal Control Cable. Signal control cable shall be in accordance with IMSA 19-1 or 20-1 and shall be stranded No. 14 AWG wire.

4040 **c. Integral Messenger Interconnect Cable.** Integral aerial interconnect cable shall be figure "8" self-supporting type cable consisting of a messenger cable and 7 conductors No. 14 AWG signal cable in accordance with IMSA 20-3.

d. 6 Pair/19 Telemetry Cable. 6 pair telemetry cable shall contain six twisted pairs of 19 gauge conductors and shall be in accordance with IMSA Specification 40-2 for underground application and IMSA Specification 40-4, integral messenger, for aerial application.

e. Fiber Optic Interconnect Cable. Fiber optic cable shall contain four stranded multimode, graded index, optic fibers with a minimum of one non-metallic central strength member. The cable shall be loose tube, all dielectric construction, suitable for outdoor use in conduit or on aerial supports. Each individual fiber shall be 62.5/125 :m diameter, core/clad, and each fiber shall be individually encased in its own gel-filled color-coded buffer. The fiber optic cable shall be constructed with Kevlar braid and outer polyethylene jackets as a minimum. If an inner jacket is used it shall be PVC. Maximum attenuation of the cable shall be 4.0 dB/km nominal, measured at room temperature at 850 nm. The bandwidth shall not be less than 160 MHz/km, also at 850 nm. Each fiber shall be continuous with no factory splices except for joining standard length cables to form longer, continuous jacketed cable to fit installation requirements. The cable shall have standard nylon rip cords. Kevlar rip cords will not be accepted. The cable shall be in accordance with the generic requirements for optical fiber and optical fiber cable per Bellcore Technical Reference TR-TSY-000020.

The exterior of the polyethylene outer cable jacket shall be stenciled so that every fifth meter on each reel is marked with a number. The fifth meter of each reel shall be marked with a 5, the tenth meter marked with a 10, and so on until the end of the reel. The stencil shall be applied to the outer jacket using permanent ink and shall be permanently engraved into the jacket to provide long lasting readability.

f. Service Cable. Traffic signal service cable shall be color coded, stranded copper No. 8 AWG wire, 3 conductor cable, type THWN.

g. Detection Wire and Sealant.

(1) Loop Detector Lead-in Cable. Loop detector lead-in cable shall be in accordance with IMSA 50-2 and shall be stranded 2 conductor No. 16 AWG, 19 strands of No. 29 wire.

The nominal capacitance between conductors shall be 187 pF/m (57 pF/ft) and 322 pF/m (98 pF/ft) between one conductor and the other conductor connected to the shield.

(2) Roadway Loop Wire. Roadway loop wire shall be 14 AWG gauge IMSA 51-5 duct-loop wire with polyvinyl chloride outer jacket of 6.3 mm (1/4 in.) diameter.

(3) Sealant. Prior to installing roadway loop wire in the roadway saw cuts, the saw cuts shall be cleaned in accordance with the requirements for the joint sealant to be used. After proper cleaning and installation of the loop wire, the saw cut shall be sealed with a joint sealant material in accordance with 906.02(a)1 or 906.02(a)2. The joint sealant material to be used shall be compatible with the roadway materials. The joint sealant material shall be installed in accordance with the applicable sealant specification. However, the joint configuration shall not apply. A copy of the sealant manufacturer's written application instructions shall be submitted to the Engineer prior to any sealant operations. If the Contractor elects to use a sealant complying with 906.02(a)2, the sealant material shall be heated in a kettle or melter constructed as a double boiler with the space between the inner and outer shells filled with oil or other heat-transfer medium. This melter shall have a positive temperature control and a mechanical agitator. A backer rod shall be used for both cold applied sealants and hot poured sealants. The sealant material shall fill the saw cut as shown on the plans. All significant or objectionable surplus joint sealant on the pavement surfaces shall be promptly removed.

h. Ground Wire. The ground wire shall be copper wire No. 6, AWG soft-drawn, solid copper in accordance with ASTM B 3.

i. Splicing Kit. Splicing kits shall contain a two piece, transparent snap-together mold body and include an epoxy and sealing compound contained in a unipak. It shall be capable of insulating and splicing nonshielded cables rated up to 5 kilovolts and multi-conductor cables rated up to 600 volts.

(g) Ground Rod and Connections. Ground rods shall be 13 mm (1/2 in.) in diameter by 2.4 m (8 ft) long with a machined point and chamfered top. They shall be made of steel with a molecularly bonded outer layer of electrolytically applied copper. The finished rod shall be cold-drawn and shall have the following minimum physical properties:

PHYSICAL PROPERTY	MINIMUM
Tensile strength	668 MPa (97,000 psi)
Yield strength, 0.2% offset	58.61 MPa (85,000 psi)
% of elongation	90 kPa (13 psi)

The ground rod and wire connection shall be made by a thermo weld process or approved equal. The welding material shall cover and secure the conductor to the rod and shall be porous free.

An acceptable alternate shall be a ground grid connection properly sized and shall consist of a shear head bolt, a "C" shaped body, nest, and wedge. The connector components shall be fabricated from an aluminum-bronze alloy, silicone-bronze alloy, and copper.

(h) Castings for Handholes. The ring and cover for handholes shall be in accordance with 910.05(b).

4130 **(i) Entrance Switch.** The entrance switch shall be a single pole, 50 amp, 120 volt circuit breaker in a NEMA type 3R enclosure. The minimum dimensions of the enclosure shall be: width 127 mm (5 in.), depth 95 mm (3 3/4 in.) and height 235 mm (9 1/4 in.). A 25 mm (1 in.) rain-tight detachable hub shall be supplied in the top of the enclosure. The enclosure shall have knockouts on the sides, bottom and back with diameters of 22 mm (7/8 in.) to 44 mm (1 3/4 in.). The enclosure shall contain the circuit breaker, an insulated solid bar for connection of AC Neutral, a separate lug for attachment of earthground, have provisions for a padlock, and shall be surface mounted.

4140 The enclosure shall be made of galvanized steel with a rust inhibiting treatment, and finished in the manufacturer's standard color of baked enamel.

(j) Conduit and Fittings.

4150 **1. Steel Conduit.** Steel conduit shall be 50 mm (2 in.) nominal diameter, threaded with a steel coupling on one end meeting applicable requirements for the conduit and the other threaded end protected by a suitable shield. The conduit shall be made of mild steel or intermediate steel. Mild steel conduit shall be in accordance with ANSI C 80.1 and UL 6. Intermediate steel conduit shall be in accordance with UL 1242, ASTM A 513 or ASTM A 135. Conduit shall be hot dipped galvanized on the interior and exterior surfaces in accordance with ANSI C 80.1.

The various conduit fittings such as bands, elbows, bodies, straps, lock nuts, and threadless connectors, shall be in accordance with Federal Specifications W-F-408. Conduit bends, elbows, and bodies shall be threaded, made of malleable iron, and galvanized. Conduit straps shall be two hole straps with a minimum thickness of 3 mm (1/8 in.) and shall be made of steel which is galvanized in accordance with ANSI C 80.1. Conduit lock nuts 10 mm to 38 mm (3/8 in. to 1 1/2 in.) in size shall be made of steel. Other sizes shall be made of malleable iron. All nuts shall be galvanized.

4160 **2. Polyvinyl Chloride Conduit.** PVC conduit shall be in accordance with schedule 40 conduit in ASTM D 1785. The PVC conduit fittings shall be in accordance with ASTM D 2466. Each length of pipe shall include a coupling.

(k) Detector Housing. The entire housing casting shall be made from aluminum alloy in accordance with ANSI 320.

(l) Certification. Unless otherwise specified, all materials covered herein shall have a type C certification in accordance with 916.

4170 **913.16 Fabric for Waterproofing.** Fabric for waterproofing shall be treated cotton in accordance with AASHTO M 117, woven glass in accordance with ASTM D 1668, or glass fiber mat in accordance with ASTM D 2178. Material furnished under this specification shall be covered by a type C certification in accordance with 916.

4180 **913.17 Packaged, Dry, Combined Materials for Mortar and Concrete.** These materials shall be in accordance with ASTM C 387. All packages shall be identified as conforming to ASTM C 387. The markings shall also show the kind and type of material, the net weight in each bag, the yield in cubic meters (cubic feet) or yield in square meters per millimeter (square feet per inch) of thickness, and the amount of water recommended for mixing to produce a 50 mm to 75 mm (2 in. to 5 in.) slump.

4190 **913.18 Geotextile for Use Under Riprap.** The material used shall consist of a non-woven geotextile consisting of strong, rot resistant, chemically stable long-chain synthetic polymer material dimensionally stable with distinct and measurable openings. The plastic yarn or fibers used in the geotextile, shall consist of any longchain synthetic polymer composed of at least 85% by weight of polyolefins, polyesters, or polyamides, and shall contain stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure. The geotextile shall be calendared or otherwise finished so that the yarns or fibers will retain their relative position with respect to each other. Slit film geotextiles will not be permitted unless approved.

The geotextile shall meet the following physical requirements:

GEOTEXTILE MATERIAL PROPERTIES

TEST	METHOD	REQUIREMENTS*
Tensile Strength	Grab Tensile Strength, ASTM D 4632	890 N (200 lbs)
Elongation	Grab Tensile Strength, ASTM D 4632	15%
Seam Strength	Grab Tensile Strength, ASTM D 4632	800 N (180 lbs)
Bursting Strength	Mullen Burst, ASTM D 3786	2.21 MPa (320 psi)
Puncture Strength	ASTM D 4833	356 N (80 lbs)
Trapezoid Tear	ASTM D 4533	225 N (50 lbs)
Ultraviolet Degradation at 150 h	ASTM D 4355	70% strength retained
Apparent Opening Size (AOS)	ASTM D 4751	AOS shall be No. 50 (300 :m) standard sieve or filter
Permeability**	ASTM D 4491 (Permittivity)	0.01 cm/sec or >

* Use value in weaker principal direction. All numerical values represent minimum average roll value and test results from any sampled roll in a lot shall meet or exceed the minimum values in the table. Lots shall be sampled according to ASTM D 4354.

4200 ** The nominal coefficient of permeability shall be determined by multiplying permittivity value by nominal thickness. The nominal thickness is measured under a normal load of 1.93 MPa (28,000 psi).

The geotextiles to be used will be selected from the list of approved Geotextiles for Use Under Riprap.

4210 A manufacturer, requesting that a geotextile be added to the approved list, shall provide a certification documenting compliance with the above requirements and a sample to the Materials and Tests Division. The certification shall be prepared by the manufacturer which addresses all the required information as shown on a sample certification form in ITM 804. No relabeled materials will be considered for approval. A specified material on the approved list will not be listed under more than one name.

When it is determined the material is acceptable, it will be added to the list of approved Geotextiles for Use Under Riprap and it may be used upon publication of the list.

4220 **913.19 Geotextile for Use with Underdrains.** This material shall consist of a non-woven needle punched or heat bonded geotextile consisting of strong, rot resistant, chemically stable long-chain synthetic polymer materials, which are dimensionally stable relative to each other including selvages. The plastic yarn or fibers used in the geotextile shall consist of at least 85% by weight of polyolefins, polyesters, or polyamides. The plastic yarn or fibers shall have stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure.

The geotextile shall be in accordance with the physical requirements as follows:

	TEST	METHOD	REQUIREMENTS ²
4230	Grab Strength	ASTM D 4632	355.8 N (80 lbs)
	Seam Strength ¹	ASTM D 4632	311.4 N (70 lbs)
	Puncture Strength	ASTM D 4833	111.2 N (25 lbs)
	Burst Strength	ASTM D 3786	896 kPa (130 psi)
	Trapezoid Tear	ASTM D 4533	111.2 kg (25 lbs)
4240	Apparent Opening size (AOS)	ASTM D 4751	Sieve No. 50 or smaller opening

Permeability	ASTM D 4491	0.1 mm/sec
Ultraviolet Degradation at 150 h	ASTM D 4355	70% strength retained

4250

¹ Values will apply to both filed and manufactured seams.

² The value in the weaker principal direction shall be used. All numerical values will represent the minimum average roll value. Test results from a sampled roll in a lot shall be in accordance with or shall exceed the minimum values shown in the table. Lots shall be sampled in accordance with ASTM D 4354.

The geotextiles to be used shall be selected from the list of approved Geotextiles for Use with Underdrains.

4260

Requests for adding geotextiles to the approved list shall be supported by a certification documenting compliance with the above requirements and a sample. The certification shall be prepared by the manufacturer in accordance with the applicable requirements of 916. No relabeled materials will be considered for approval. A specified material on the approved list will not be listed under more than one name. When it is determined the material is acceptable, it will be added to the list of approved Geotextiles for Use with Underdrains and it may be used upon publication of the list.

4270

A manufacturer, requesting that a geotextile be added to the approved list, shall provide a certification documenting compliance with the above requirements and a sample to the Materials and Tests Division. The certification shall be prepared by the manufacturer in accordance with 916.03(h). No relabeled materials will be considered for approval. A specified material on the approved list will not be listed under more than one name. When it is determined the material is acceptable, it will be added to the list of approved Geotextiles for Use with Underdrains and it may be used upon publication of the list.

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913.20 Geotextile for Silt Fence. The silt fence fabric shall consist of a woven or non-woven geotextile consisting of strong, rot resistant, chemically stable long-chain synthetic polymer materials, which are dimensionally stable relative to each other including selvages. The plastic yarn or fibers used in the geotextile shall consist of at least 85% by weight of polyolefins, polyesters, or polyamides. The plastic yarn or fibers shall have stabilizers and inhibitors added to the base plastic to make the filaments resistant to deterioration due to ultraviolet and heat exposure.

The geotextile shall be in accordance with the guidelines of AASHTO-AGC-ARTBA, Task Force 25 and AASHTO M 288.

The geotextile shall be in accordance with the physical requirements as follows:

	TEST	METHOD	REQUIREMENTS ¹	
			Wire Fence Supported	Self Supported
4290	Grab Strength	ASTM D 4632	41 kg (90 lb)	41 kg (90 lb)
	Elongation at 20 kg (45 lb)	ASTM D 4632		50% Max.
4300	Apparent Opening Size ²	ASTM D 4751 0.84 mm	No. 20 0.84 mm	No. 20
	Permittivity ²	ASTM D 4491	0.01 sec ⁻¹	0.01 sec ⁻¹
	Ultraviolet Degradation at 500 h	ASTM D 4355	70% strength retained	70% strength retained

- 4310
1. The value in the weaker principal direction shall be used. All numerical values will represent the minimum average roll value. Test results from a sampled roll in a lot shall be in accordance with or shall exceed the minimum values shown in the above table. The stated values are for non-critical, non-severe conditions. Lots shall be sampled in accordance with ASTM D 4354.
 2. The values reflect the minimum criteria currently used. Performance tests may be used to evaluate silt fence performance if deemed necessary by the Engineer.

Material furnished under this specification shall be covered by the type of certification specified in the Frequency Manual and in accordance with 916.

4320 **913.21 Geogrid for Stabilization or Modification.** The geogrid shall be in accordance with the property requirements as follows:

PROPERTY Min.	TEST METHOD	UNIT	VALUE,
Aperture Size	Calibered	mm (in.)	19 x 19 (0.75 x 0.75)
Open Area	COE CWO2215	percent	> 50, <u>≤</u> 80

4330	Tensile Modulus, machine direction or cross machine direction	GRI, GG1 ^{1, 3}	N/m (lb/ft)	146,000 (10,000)
	Ultimate Strength, machine direction or cross machine direction	GRI GG1 ^{2,3}	N/m (lb/ft)	11,670 (800)
4340	1. Secant modulus at 5% elongation measured by Geosynthetic Research Institute Test Method GG1, Geogrid Tensile Strength. No offset allowance shall be made in calculating secant modulus. 2. Ultimate strength measured by Geosynthetic Research Institute Test Method GG1, Geogrid Tensile Strength. 3. Minimum average roll values shall be in accordance with ASTM D 4759.			

4350 During all periods of shipment and storage, the geogrid shall be protected from temperatures greater than 60EC (140EF), mud, dirt, dust, and debris. The manufacturer's recommendations shall be followed with regard to protection from direct sunlight. At the time of installation, the geogrid will be rejected if it has defects, tears, punctures, flaws, deterioration, or damage incurred during manufacture, transportation, or storage. All damaged portions of geogrid for the entire width shall be replaced.

4360 The geogrids to be used shall be selected from the Department's list of approved Geogrids for Subgrade Stabilization or Modification. Requests for adding a geogrid to the approved list shall be supported by means of a type A certification which documents compliance with the above requirements and a 1 running meter (1 running yd) sample. The certification shall be prepared by the manufacturer in accordance with the applicable requirements of 916. No relabeled materials will be considered for approval. A specified material shown on the approved list will not be listed under more than one name. When it is determined that the material is acceptable, the geogrid will be added to the list of approved Geogrids for Subgrade Stabilization or Modification.

SECTION 914 – ROADSIDE DEVELOPMENT MATERIALS

914.01 Special Topsoil for Roadside Development. This topsoil shall consist of loose friable soil, free of refuse, stumps, large roots, rocks over 50 mm (2 in.) in diameter, brush, weeds, or other material which would be detrimental to the proper development of vegetative growth. It shall be capable of supporting normal vegetation as demonstrated by the growth of healthy vegetation on it. It shall not be taken from a source known to contain any of the noxious weeds defined as such in the Indiana State Seed Law, IC 15-4-1.

Topsoil shall have a pH value of 6.2 to 7.4. Testing for pH value shall be performed in the field in accordance with the procedure set out in the Purdue University Agricultural Experiment Station bulletin No. 635 or in a qualified laboratory in accordance with the procedure set out in the Cornell Experiment Station Bulletin 960, using a one to one Soil-Water Suspension. Agricultural limestone may be added to topsoil in order to raise the pH to meet specification requirements. Topsoil shall not be incorporated into the work until it is approved.

914.02 Blank.

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914.03 Fertilizer. Fertilizer shall be standard commercial fertilizer with an analysis of 12-12-12.

Tests will not be required, but fertilizer standards shall be governed by the rulings of the Indiana State Seed Commissioner.

914.04 Grass and Legume Seed. Grass and Legume seed in the quantities and varieties required shall be furnished full-tagged and delivered in properly designated packages or bags as directed. Seeds shall be in accordance with the following requirements.

30

Seed of warm season grasses, forbs, or aquatic species shall be delivered to the project site individually packaged by species. Warm season grass and forb seed shall be purchased from lots for which test results are provided. Testing will not be required for aquatic species. When normal germination testing is not practical for forb species, a tetrazolium test shall be conducted to determine seed viability.

Seeds shall contain none of the noxious weeds listed herein nor any that are listed in the Acts of the General Assembly of the State. Noxious weeds are Canada Thistle, Field Bindweed, Johnson Grass, Perennial Peppergrass, Perennial Sowthistle, Quack Grass, Russian Knapweed, and Wild Garlic.

40

Clover shall be free from dodder with no tolerance allowed. Lespedeza will be allowed no more than 200 dodder/kg (90 dodder/lb) and 20 giant foxtail per kg (45 giant foxtail per lb).

Requirements noted above are minimum and trade allowances will not be permitted.

50

Seed shall be purchased from sources of supply that have been sampled, tested, and reported by the State Seed Commissioner, Purdue University, West Lafayette, Indiana, and found to be satisfactory. Seed of warm season grasses shall be tested by the State Seed Commissioner or an independent laboratory. Seed of forbs shall be tested by an independent laboratory. Test results by independent laboratories shall be signed by a Registered Seed Technologist. Test results shall be submitted to the State Seed Commissioner, and a copy to the Division of Materials and Tests. This report is required before seed is sown. Such test report shall be no more than nine months old at the time seed is used and the use of the seed shall be subject to approval.

60 Seed which has been tested by the State Seed Commissioner may be used without further testing provided each bag of seed bears a tag showing the seed meets the requirements of the Standard Specifications.

Seed which meets the weed seed tolerance, but does not comply with the purity or germination requirements, or both, may be used provided the percentage of purity or the percentage of germination is not more than 10% below the minimum specified and that the result obtained from the following formulae does not exceed the maximum percent of weed seeds permitted.

70 $W \times P \times G = M$ or less

P = $\frac{\text{Minimum Specified Purity}}{\text{Actual Purity}}$

G = $\frac{\text{Minimum Specified Germination}}{\text{Actual Germination}}$

W = Actual percent of weed seeds

P = Purity Factor

80 G = Germination Factor

M = Maximum percent of weed seeds permitted

If such seeds are selected for use, the amount to be used shall be increased in accordance with the following formula except the amount used shall not be less than that specified.

$$\text{Amount to be used} = \text{Amount specified} \times P \times G$$

VARIETY		Percentages of Weed Seed Content (Not more than)
Alfalfa	Medicago sativa	0.5
Alsike Clover	Trifolium hybridum	0.5
Alta Fescue or Ky. 31	Festuca elatior	
Fescue	(var. arundinacea)	0.75
Birdsfoot Trefoil	Lotus corniculatus	0.5
Chewings Fescue	Festuca rubra (var. fallax)	0.5
Crown Vetch (Penngift, Emerald, Chemung)	Coronilla	0.5
English Perennial Rye	Lolium perenne	0.5
Kentucky Bluegrass	Poa prateusis	0.5
Korean Lespedeza	Lespedeza stipulacea	0.75
Sericea Lespedeza	Lespedeza sericea	0.75
Ladino Clover	Trifolium repens (var. latum)	0.5
Lemons Alkali Grass	Puccinellia airoides(Lemons)	0.5
Orchard Grass	Dactylis glomerata	0.5
Red Clover	Trifolium pratense	0.5
Red Fescue	Festuca rubra	0.5
Red Top	Agrostis alba	0.75
Rough Stalked Meadowgrass	Poa trivialis	0.5
Rye, Agricultural	Secale cereale	0.5
Rye, Annual	Lolium multiflorum	0.5
Sheeps Fescue	Festuca orina	0.5
Smooth Brome Grass	Bromus inermis	0.95
Sweet Clover-white (Scarified)	Melilotus alba	0.5
Sweet Clover-yellow (Scarified)	Melilotus officinalis	0.5
Timothy	Phleum pratense	0.5
White Clover	Trifolium repens	0.75

VARIETY		Percentages of Purity (Not less than)
Alfalfa	Medicago sativa	99
Alsike Clover	Trifolium hybridum	97
Alta Fescue or Ky. 31	Festuca elatior	
Fescue	(var. arundinacea)	98
Birdsfoot Trefoil	Lotus corniculatus	98
Chewings Fescue	Festuca rubra (var. fallax)	97
Crown Vetch (Penngift, Emerald, Chemung)	Coronilla	95
English Perennial Rye	Lolium perenne	95
Kentucky Bluegrass	Poa prateusis	85
Korean Lespedeza	Lespedeza stipulacea	98
Sericea Lespedez	Lespedeza sericea	98
Ladino Clover	Trifolium repens (var. latum)	98
Lemons Alkali Grass	Puccinellia airoides (Lemons)	85
Orchard Grass	Dactylis glomerata	85
Red Clover	Trifolium pratense	98
Red Fescue	Festuca rubra	95
Red Top	Agrostis alba	90
Rough Stalked Meadowgrass	Poa trivialis	85
Rye, Agricultural	Secale cereale	99
Rye, Annual	Lolium multiflorum	95
Sheeps Fescue	Festuca orina	97
Smooth Brome Grass	Bromus inermis	85
Sweet Clover-white (Scarified)	Melilotus alba	98
Sweet Clover-yellow (Scarified)	Melilotus officinalis	98
Timothy	Phleum pratense	90
White Clover	Trifolium repens	97

VARIETY		Percentages Actual Germination (Not less than)
Alfalfa	Medicago sativa	85*
Alsike Clover	Trifolium hybridum	85*
Alta Fescue or Ky. 31	Festuca elatior	
Fescue	(var. arundinacea)	85
Birdsfoot Trefoil	Lotus corniculatus	80*
Chewings Fescue	Festuca rubra (var. fallax)	75
Crown Vetch (Penngift, Emerald, Chemung)	Coronilla	70*
English Perennial Rye	Lolium perenne	90
Kentucky Bluegrass	Poa pratensis	80
Korean Lespedeza	Lespedeza stipulacea	80*
Sericea Lespedeza	Lespedeza sericea	80*
Ladino Clover	Trifolium repens (var. latum)	85*
Lemons Alkali Grass	Puccinellia airoides (Lemons)	80
Orchard Grass	Dactylis glomerata	80
Red Clover	Trifolium pratense	90*
Red Fescue	Festuca rubra	85
Red Top	Agrostis alba	80
Rough Stalked Meadowgrass	Poa trivialis	75
Rye, Agricultural	Secale cereale	80
Rye, Annual	Lolium multiflorum	90
Sheeps Fescue	Festuca orina	75
Smooth Brome Grass	Bromus inermis	80
Sweet Clover-white (Scarified)	Melilotus alba	85*
Sweet Clover-yellow (Scarified)	Melilotus officinalis	85*
Timothy	Phleum pratense	85
White Clover	Trifolium repens	90*

* including not more than 25% hard seeds

914.05 Mulch.

(a) Mulch for Seeding. Mulch for seeding may consist of straw; excelsior mulch; wood cellulose fiber mulch; excelsior blanket; paper mat; or straw mat. All mulch shall be reasonably free from primary noxious weeds in accordance with 914.04.

100

1. Excelsior Mulch. Excelsior mulch shall consist of wood fibers cut from sound green timber. The average length of the fibers shall be 100 to 150 mm (4 to 6 in.). The cut shall be made in such a manner as to provide maximum strength of fiber, but at a slight angle to the natural grain of the wood so as to cause splintering of the fibers when weathering in order to provide adherence to each other and to the soil.

2. Wood Cellulose Fiber. Wood cellulose fiber mulch shall be made from wood chip particles manufactured articularly for discharging uniformly on the ground surface when disbursed by a hydraulic water sprayer. It shall remain in uniform suspension in water under agitation and blend with grass seed, and fertilizer when permitted, to form a homogeneous slurry. The mulch fibers shall intertwine physically to form a strong moisture holding mat on the ground surface. The mulch shall be heat processed so as to contain no germination or growth inhibiting factors. It shall be non-toxic and colored green. The percent of moisture content shall be determined in accordance with 621.13(c), except material containing more than 15% will be rejected. The ash content shall not exceed 1.5%. One hundred grams of oven dried material saturated in water, drained, and weighed shall hold a minimum of 1000 grams of water.

3. Excelsior Blanket. Excelsior blanket shall consist of a machine produced mat of wood excelsior with 80% of the fibers to be 150 mm (6 in.) or longer. The wood from which the excelsior is cut shall be properly cured to achieve curled and barbed fibers. The blanket shall have a consistent thickness, with the fibers evenly distributed over the entire area of the blanket. The excelsior blanket shall be covered on the top side with a 75 mm by 25 mm (3 in. by 1 in.) leno weave, twisted kraft paper yarn netting having a high wet strength, or a biodegradable extruded plastic mesh netting having an approximate minimum opening of 16 mm by 16 mm (5/8 in. by 5/8 in.) to an approximate maximum opening of 50 mm by 25 mm (2 in. by 1 in.). The netting shall be entwined with the excelsior mat for maximum strength and ease of handling. The minimum roll width shall be 1.2 m (4 ft). The mass of the material shall be not less than 0.4 kg/m² (0.7 lb/sq yd), constant mass, air dry. The rolls shall be packaged with suitable protection for outdoor storage on the project site in a manner which protects them from biodegradation prior to use.

4. Paper Mat. Paper mat shall consist of a knitted construction of photodegradable, polypropylene yarn with uniform openings interwoven with strips of biodegradable paper. The rolls shall be packaged with suitable protection for outdoor storage at a construction site in a manner which protects them from biodegradation prior to use. The mass of the paper shall be a minimum of 0.069 kg/m² (0.125 lb/sq yd). Roll sizes shall have a minimum width of 1.5 m (5 ft).

5. Straw Mat. Straw mat shall consist of a machine produced mat consisting of at least 90% of the total dry mass being clean straw from agricultural crops, with the exception that up to 30% of the total dry mass may be coconut fibers in lieu of an equal percentage of straw. Paper or paper related products shall not be permitted as component in the straw mat. The straw shall be evenly distributed throughout the mat to form a thickness of 13 mm " 3 mm (1/2 in. " 1/8 in.). The top side of the mat shall be covered with a photodegradable/biodegradable plastic mesh which shall be substantially adhered to the straw by a knitting process using photodegradable/biodegradable thread. The rolls shall be packaged with suitable protection for outdoor storage at a construction site in a manner which protects them from biodegradation prior to use. The average dry mass of the straw mat shall not be less than 0.4 kg/m² (0.7 lb/sq yd). The minimum roll width shall be 1.8 m (6 ft).

(b) Mulch for Plants. Mulch for plants shall consist of broken corncobs, wood chips, chopped bark, size No. 5 gravel or crushed stone in accordance with 904.02(e), except 0% to 5% may pass the 75 :m (200) sieve, or other approved materials. The particles of wood chips, chopped bark, and corncobs shall contain no more than 10% passing the 12.5 mm (1/2 in.) screen and 100% shall pass the 75 mm (3 in.) screen. Wood chips shall be from green, hardened, deciduous trees. Broken corncobs shall be no longer than 100 mm (4 in.).

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914.06 Leguminous Inoculants. The inoculants for treating leguminous seeds shall be standard pure culture of nitrogen fixing bacteria. They shall be no more than one year old at the time of use and shall be subject to approval. Directions of the manufacturer on containers of inoculants shall be followed when inoculating seed.

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914.07 Sod. Sod shall consist of fibrous, well rooted, bluegrass, fescue or other approved grass cut to a height of 50 to 75 mm (2 to 3 in.). Edges of sod shall be cut cleanly, either by hand or machine, to a uniform minimum thickness of 19 mm (3/4 in.) or more. The roots shall be exposed in the sod strip to allow the sod to be handled without undue tearing or breaking. The sod strip shall be of a uniform width of no less than 406 mm (16 in.) and no less than 6.1 m (2 ft) in length. Sod shall be free from all primary noxious weeds in accordance with 914.04. Acceptance in the field before cutting shall not preclude rejection when delivered to the work if such contamination is found.

180

Nursery sod shall meet applicable requirements set out above and shall be a variety or blend of Kentucky bluegrass or fescue. It shall comply with nursery inspections and plant quarantine regulations of the states of origin and destination as well as with Federal regulations governing interstate movement of nursery stock. A valid copy of the certification of nursery inspection shall accompany each shipment.

190

914.08 Plant Materials. If the plant material is shown on the Schedule of Pay Items as plant, the Contractor shall submit its source of supply for each plant material for approval prior to delivery to the project site. This plant list shall include the name of the source of supply and the location where the plants were grown. A certification that the plants are available at this source, that the plants were grown at the prescribed location, and that there is a firm commitment for their purchase at the time of certification shall be provided. These procedures shall be followed for approval of alternate sources when the originally approved source is unable to furnish plants at the time when needed. Plants shall be in accordance with the requirements set out herein. Unless otherwise specified, all plant material shall be acquired from zones 4, 5, or 6. However, plant material shall be acquired from zones no further than 1/2 zone south of the zone in which the project is located. Hardiness zones shall be determined from the Plant Hardiness Zone Map, Miscellaneous Publications No. 1475, Agricultural Research Service, United States Department of Agriculture, published by the U. S. Government Printing Office, Washington, D.C. The Contractor shall have a copy of this map.

200 If the plant material is shown on the Schedule of Pay Items as seedlings, the Contractor shall choose a source which is shown on the approved list of sources that is maintained by the Department. This list will specify the sources that are currently on an immediate use basis. If the source is not on the list, then the same procedure shall be followed as stated above for plants to obtain approval.

210 **(a) Quality of Plant Materials.** All plants shall be first class and representative of the normal species or varieties, true to type, and standard form. Unless otherwise specified, all plants shall be nursery grown stock that had been transplanted or rootpruned two or more times according to the kind and size of plant. The root system shall be vigorous and well developed. The branch system shall be developed normally. All plants shall be free from disfiguring knots, sun-scald, injuries, abrasions of the bark, dead or dry wood, broken terminal growth, or other objectionable disfigurements.

(b) Plant Names. Plants shall be true to name, following standard botanical and common nomenclature as adopted by the American Joint Committee on Horticultural Nomenclature given in the current edition of Standardized Plant Names. All trees delivered shall be tagged legibly with the names and sizes of the trees.

220 All delivered shrubs shall be tagged legibly with the name and size of the shrub when "Tag Each" is indicated on the summary list. Otherwise, each bundle shall be tagged. If shrubs are separated individually when delivered, 20% of each species shall be tagged. A tag with the name and size of the shrub printed thereon shall be used for each species. A 25 mm (1 in.) band of non-toxic paint shall be applied to the stem of seedlings or "whips," prior to delivery, in lieu of tags. If tags are required, they shall remain attached to shrubs for the duration of the contract.

230 **(c) Substitutions.** Substitutions of plants in size and kind shall be made only after proper execution of an extra work agreement and then only when sufficient evidence has been shown that the specified stock could not be secured.

(d) Grading Standards. Grading of plants shall be in accordance with the American Association of Nursery Horticultural Standards of the current ASNS, ANSI Z 60.1 as revised herein and on the plans.

240 **(e) Nursery Inspection and Plant Quarantine.** All plants shall be free from plant diseases and insect pests. Shipments of plants shall be in accordance with nursery inspection and plant quarantine regulations of the states of origin and destination as well as with Federal regulations governing interstate movement of nursery stock. A valid copy of the certification of inspection shall accompany each package, box, bale, or carload shipped or otherwise delivered.

(f) Balled and Burlapped Plants. Balled and burlapped plants shall be dug so as to retain as many fibrous roots as possible and shall come from soil which forms a firm ball. The soil in the ball shall be the original and undisturbed soil in which the plant was grown and shall be free of noxious weeds and weed seeds. The plant shall be dug, wrapped, transported, and handled in such a manner that the soil in the ball will not be loosened enough to cause stripping of the small and fine feeding roots or cause the soil to drop away from such roots. Any indication of manufactured earth balls or mishandling of the plant will be cause for rejection. The shape and size of the ball shall be as specified in the ASNS as revised herein and shown on the plans.

(g) Container Grown Plants. Plants which are furnished in containers shall be well rooted and established in the container in which they were shipped. An established container grown plant shall be a plant transplanted into a container and grown in that container sufficiently long for the new fibrous roots to have developed so that the root mass retains its shape and holds together when removed from the container.

(h) Bare Rooted Plants. The minimum root system of bare rooted trees or shrubs shall be in accordance with the standards stated in the ASNS. Bare rooted plants shall be dug only when the air temperature exceeds $\geq$ C (35 $\geq$ F). Particular attention shall be given to the fibrous roots. The maximum time lapse between loading for shipment and delivery to the work or approved storage site shall be four days unless other shipping arrangements are approved.

(i) Collected Plants. Collected plants, when specified in connection with any species or variety, shall not be nursery grown, but shall have been grown under natural conditions at the location from which they were procured. They may be balled and burlapped or bare roots as specified in the plant list on the plans. In either case, the collected material shall be in accordance with the applicable requirements given in the current issue of ASNS for quality, size, ball, and grade.

(j) Forms, Shapes, and Condition of Plants. Vines and groundcover plants shall be in accordance with grades and specifications shown in the ASNS unless otherwise specified.

Plants which have been cut back from larger grades to meet specifications will not be acceptable. Plants designated on the plans as street trees, specimen, extra heavy, clump, or of other like import shall be in accordance with the standards as given in the ASNS for the special type specified.

Trees shall have straight trunks, be well branched, and have symmetrical tops. There shall be no cuts of limbs over 19 mm (3/4 in.) in diameter which have not completely healed over. Each tree shall have the top and root characteristics of its variety and growth that are typical of such trees in this region. Deciduous trees, unless otherwise specified, shall have branching between 1/4 and 1/2 of the distance of their height from the ground. Street trees, if so specified, shall be of uniform branching height. Bush form, when specified, shall be branching at the base of the plant or within 300 mm (12 in.) of the base. Clumps, when specified, shall have three or more main leaders or trunks starting at the ground. At least two of these shall be of the caliber specified.

(k) Inspection. Plant materials shall be subject to inspection at any time during the life of the contract. Such inspection shall not be construed as final acceptance of the plants involved. Any stock which is not in accordance with these specifications will be rejected and shall be removed from the project.

Balled and burlapped plants may have the ball opened for inspection, at the option of the Department, to determine if the root system is sufficient to ensure plant growth. If after breaking open, the ball is found to be acceptable, payment for the destroyed plant will be made at 50% of the contract price for the plant involved.

Nursery stock may be inspected at the nursery before digging or shipping and sealed with Department seals. If not inspected and sealed at the nursery, it shall be done at a final collecting point at or adjacent to the project and prior to planting, unless otherwise specified in writing. Notification shall be made a minimum of three days in advance of delivery of unsealed plants. Large quantities of small plant material such as shrubs, seedlings, vines, groundcovers, etc., shall be sealed in a satisfactory manner. Sealing of plants shall not be considered as final acceptance and shall not waive the responsibility to furnish, plant, and maintain material that complies with the specifications.

(l) Shipment. All precautions that are customary in good trade practice shall be taken to ensure the arrival of the plants in good condition. Plants shall be packed or covered in such a manner as to ensure adequate protection against damage while in transit. The roots of bare root plants shall be protected with wet straw or other suitable material to ensure the arrival at destination with the roots in a moist condition. When shipment is made in an enclosed vehicle, the vehicle shall be adequately ventilated to prevent over heating of the plants in transit.

(m) Certification. Certifications from all plant supply sources shall be furnished certifying that all plants furnished are in accordance with 914.08. These certifications shall be submitted monthly and shall contain the information as indicated on the suggested form in ITM 804.

914.09 Miscellaneous Material.

330 **(a) Water.** Water used in the planting or care of vegetation shall be free from oil, acids, alkalis, salts, or any substance injurious to plant life. Water from streams, lakes, ponds, or similar sources shall not be used unless approved.

(b) Stakes for Bracing and Anchoring. Wood stakes for bracing or supporting trees shall be of rough cypress, cedar, locust, oak, or other approved wood free from knots, rot, cross grain, or other defects that would impair the strength of the stake for which it is to be used. Wood stakes shall be a minimum of 50 mm by 50 mm (2 in. by 2 in.) square in cross section and of adequate length. The wood bracing stakes shall be painted or stained dark green. Delineator posts in accordance with 910.15 may be used except they shall be painted dark green.

340 An alternate staking and bracing method using a solid rubber support cord with metal hooks and stakes, and plastic stake disk system, may be used.

(c) Tree Wound Dressing. Dressing for treating tree wounds or cuts shall be either:

1. an approved black asphaltum base antiseptic paint;
2. an approved black paint consisting of Bordeaux Mixture, raw linseed oil, and lampblack; or
- 350 3. an approved black paint consisting of zinc oxide, raw linseed oil, and lampblack.

(d) Porous Material. Porous material for tree root protection may be gravel, crushed stone, slag, or other porous material varying in size from 25 to 75 mm (1 to 3 in.) and shall be approved before being used.

(e) Pipe. Pipe for underdrains shall be in accordance with 907 or 908. The size and type shall be as specified.

360 **(f) Staples.** Staples shall be made from 3.0 mm (No. 11 gage) or heavier wire, width 25 or 50 mm (1 or 2 in.) at the throat and 150 mm (6 in.) from top to bottom after bending. The staples shall be packaged in cartons.

(g) Plastic Net. Plastic net shall consist of photodegradable, longchain synthetic polymer plastic yarn, either extruded oriented or woven into a net with the yarns fixed at each intersection such that they retain their relative positions with respect to each other. The plastic net shall have a square mesh opening of approximately 19 mm by 19 mm (3/4 in by 3/4 in.). The plastic net shall have a minimum tensile strength of 89 N (20 lbs) over a 75 mm (3 in.) width in the machine direction and 67 N (15 lbs) over a 75 mm (3 in.) width in the transverse direction. The plastic net shall have a nominal mass of 15.6 " 2.2 g per m² (2.8 " 0.4 lbs per 1000 sq ft). The plastic net shall be furnished in rolls which can be easily handled and the rolls shall be packaged in a suitable protection for outdoor storage at a construction site, which protects the material from degradation prior to use. Roll sizes shall have a minimum width of 1.8 m (6 ft).

Material furnished under this specification shall be covered by a type C certification in accordance with 916.

SECTION 915 – BRIDGE PILES AND BEARINGS

915.01 Steel Shell Encased Concrete Piles and Epoxy Coated Steel Shell Encased Reinforced Concrete Piles.

(a) General Requirements. Steel shell encased concrete piles and epoxy coated steel shell encased reinforced concrete piles, as designated herein, shall consist of fluted steel, or rounded straight seamed, spiral seamed, or seamless steel pipes which, after being driven, are filled with class A concrete. The steel shell encasement shall be uncoated unless an epoxy coating, in accordance with 915.01(d) is specified.

Steel pile shells shall be of the diameter and minimum wall thickness shown on the plans. All sections shall be one integral piece, substantially cylindrical, except as otherwise required for end sections of the outside diameter specified. All steel pile shells shall be of sufficient strength to withstand driving to the required penetration and bearing.

The tips of shells shall be equipped with conical driving points or flat closure plates. Conical driving points shall be of sufficient dimensions to ensure adequate joint and driving strength. The end of the shell shall have full bearing on the face of the point or against a shoulder inside the point. Unless otherwise permitted, the point shall be conical with a 60 to 90 degrees angle between faces. The point shall be substantially of the same diameter as the end of the shell and butt welded to the end of the lowest section.

If flat closure plates are used, they shall be non-reinforced and of a minimum thickness of 19 mm (3/4 in.) for shells 324 mm (12 3/4 in.) outside diameter and smaller, and 25 mm (1 in.) thick for shells 356 mm (14 in.) outside diameter. For shells larger than 356 mm (14 in.) outside diameter, the plates shall be designed to meet the particular cases. Flat plates shall have a diameter approximately 13 mm (1/2 in.) greater than the diameter of the shell and be fillet welded to the shell, using two passes or beads.

If necessary to facilitate handling, shells may be furnished in sections to be welded in the field to form the final integral lengths required.

40 The manufacturer shall provide a mill certification showing heat numbers and test results for the specified tests. Each pile shall be stenciled to show the diameter, wall thickness, and heat numbers for the verification of the certifications. The certifications be delivered before the pile shells are driven.

(b) Fluted Steel Pile Shells. Fluted steel pile shells shall have a minimum tensile strength of 345 MPa (50,000 psi) when tested in accordance with ASTM A 370. Test specimens for determination of tensile strength shall be taken longitudinally adjacent to the crest of the flute. The diameter of fluted steel shells shall be measured from crest to crest of flutes.

50 A sufficient taper will be allowed to permit no less than 150 mm (6 in.) telescoping at the joints. The lowest section shall taper approximately 25 mm (1 in.) in 1.2 m (4 ft) from an 203 mm (8 in.) tip to the specified diameter of the upper end. Fluted steel pile shells with a taper of 25 mm (1 in.) in 2.1 m (7 ft) on the lowest section of long piles may be used provided a minimum of approximately 1.5 m (5 ft) of the top of the pile below cutoff elevation is the full diameter as shown on the plans.

(c) Rounded Steel Pipe Shells. Rounded steel pipe shells, except for end finish, shall be in accordance with ASTM A 252, grade 2 or 3. Welded pipe may be welded with straight or spiral seams.

60 **(d) Epoxy Coating for Piles.** Only powdered epoxy resin from the Department's list of approved coating materials shall be used for the epoxy coating of steel pile shells and steel H piles.

The patching or repair material shall be compatible with the coating and shall be made available by the coating manufacturer. The material shall be suitable for repairs made to coated areas damaged during fabrication or handling.

70 The coating color shall contrast with the color of iron oxide. All coated piles furnished for a structure shall be the same color. The patching or repair material shall also be the same color as the original coating material.

1. Prequalification of Organic Coatings for Steel Piles. The coating product shall be a 100% solids, heat curable, thermosetting, dry powered epoxy coating. Coating manufacturers who request to have their product added to the Department's list of approved epoxy coatings for steel shall supply the information as follows:

80 **a. Product Data Sheet.** A product data sheet which shall specify the method of surface preparation, the thermal treatments before and after coating application, the coating application procedure, and the product name and description of the patching material.

b. Fingerprint. The fingerprint shall include the method of test, such as infrared spectrometry or thermal analysis, and a generic description of the product.

c. Materials Safety Data Sheets. Current Materials Safety Data sheets shall be supplied for the product and the patching material.

d. Laboratory Report. A dated laboratory report which shall substantiate full compliance with the following test requirements.

90 **(1) Tensile Strength and Elongation.** The tensile strength and elongation of the coating material shall be tested in accordance with ASTM D 2370 with a rate of elongation of 10% to 20%/min. The minimum tensile strength shall be 56 MPa (8,000 psi). The minimum elongation shall be 5%.

100 **(2) Impact Resistance.** The impact resistance of the coating shall be tested in accordance with ASTM G 14 using a 16 mm (5/8 in.) diameter tip, and a 0.03 mm (12 mil) minimum coating thickness of a 3.2 mm (1/8 in.) thick panel at 23EC (73EF). Three tests shall be performed. The minimum acceptable value shall be 9.0 N·m (80 Lbf in.) of impact with no visible breaks in the coating.

(3) Abrasion Resistance. The abrasion resistance of the coating shall be tested by means of a Tabor Abraser or its equivalent, using CS-10 wheels and a 1,000 g (2.2 lb) load. The maximum allowable mass loss shall not exceed 100 mg per 1,000 cycles.

110 **(4) Salt Fog.** The weathering resistance of the coating shall be tested by means of a salt spray cabinet following ASTM B 117 for 1,000 h. The coating shall not blister or exhibit corrosion, discoloration, or loss of adhesion away from the scribed area.

2. Application. The application of the epoxy coating shall be at an enclosed plant, equipped with environmental controls and automated blasting equipment. This equipment shall facilitate surface preparation and coating application in accordance with the manufacturer's recommendations and in accordance with additional requirements set out herein. The application process shall be performed by a continuous, balanced system where cleaning of the surface and application of the coating are performed at the same rate.

120 **a. Surface Preparation.** The pile surface shall be blast cleaned in conformance with SSPC-SP-10 Near White Metal Blast. The cleaning media shall produce an anchor pattern profile of 50 :m (2 mils) minimum. Any raised slivers, scabs, laminations or bristles of steel remaining on the newly cleaned surface shall be removed by abrasive sanders. All traces of grit and dust from the blasting shall be removed.

b. Coating Application. The coating shall be applied immediately to the cleaned surface and before visible oxidation of the surface occurs. The coating shall be applied in accordance with the manufacturer's recommendations. The recommendations shall address the equipment required for proper application, the number of coats of epoxy, cure time between coats, cure time before placing in service, and any other information needed by the Department to ensure proper performance of the material.

(1) Thickness. Thickness of the cured coating shall be measured on a representative number of piles from each production lot by the same method required by ASTM G 12 for measurement of film thickness of pipeline coatings on steel. The minimum coating thickness for fusion bonded epoxy shall be 200 :m (8.0 mils) for individual measurements and 300 :m (12 mils) for the average.

(2) Cure. The coating film shall be cured and post cured in accordance with the manufacturer's recommendations. A representative proportion of each production lot shall be checked by the coating applicator using a method found most effective for measuring cure to ensure that the entire production lot is in a fully cured condition.

(3) Continuity of Coating. After cure, the epoxy coating shall be checked by the applicator for continuity of coating and shall be free from holes, voids, contamination, cracks, and damaged areas. There shall not be more than two holidays, which are pinholes not visually discernible, in any linear foot of the coated pile. A holiday detector shall be used in accordance with the manufacturer's instructions to check the coatings for holidays. A 67 1/2 volt Tinker and Rasor Model M-1 detector or its equivalent shall be used.

3. Certification. Material furnished under this specification shall be covered by a type C certification in accordance with 916. In addition, a certificate of compliance prepared by the applicator shall be furnished for each shipment of coated piles. The certificate of compliance shall state that the piles have been coated in accordance with the manufacturer's requirements; that thickness, continuity, and flexibility tests of the coating have been performed; and that the test results comply with the requirements outlined herein. Test results shall be retained by the applicator and made available for inspection upon request for a period of seven years.

915.02 Steel H Piles and Epoxy Coated Steel H Piles. Steel H piles and epoxy coated steel H piles shall be of the shape and dimensions shown on the plans or as otherwise specified. The steel shall be in accordance with AASHTO M 183. Steel H piling shall be handled in the same manner and with the same care as required in 711.55. The piles shall be uncoated unless an epoxy coating, in accordance with 915.01(d), is specified.

The manufacturer shall provide a mill certification showing heat numbers and test results for the specified tests. Each H pile shall be stenciled to show the manufacturer's name, the specifications, size and mass of section, and heat numbers for verification of the certification. The certification shall be submitted at the time of delivery of the piles.

915.03 Wood Piles. Wood piles shall be in accordance with 911.01(e) or 911.02(c) as specified.

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915.04 Elastomeric Bearings.

(a) Description. Elastomeric bearings as herein specified shall include plain bearings, consisting of elastomer only, and laminated bearings, consisting of layers of elastomer restrained at their interfaces by bonded laminates. The grade of the material shall be as shown on the plans.

190

(b) Materials. The elastomer portion of the elastomeric compound shall be 100% virgin natural polyisoprene known as natural rubber, or 100% virgin chloroprene known as neoprene. The cured compound shall be in accordance with Table A for natural rubber, or Table B for neoprene, depending on which type is furnished. Compounds of nominal hardness between the values shown may be used and the test requirements interpolated. When test specimens are cut from the finished product, a " 15% variation in tensile strength and ultimate elongation will be allowed.

TABLE A

ASTM Standard	Physical Properties	50 Duro	60 Duro	70 Duro
	Hardness ASTM D 2240	50 " 5	60 " 5	70 " 5
	Tensile strength, Min.(psi)	(2500)	(2500)	(2500)
	ASTM D 412 kPa	17,240	17,240	17,240
	Ultimate elongation, Min. %	450	400	300
	Heat Resistance			
D 573	Change in durometer hardness, max. Points	+ 10	+ 10	+ 10
70 hr.	Change in tensile strength, max. %	-25	-25	-25
@ 70EC	Change in ultimate elongation, max. %	-25	-25	-25
(158EF)				
	Compression Set			
D 395 Method B	22 h @ 70EC (158 EF), max. %	25	25	25
	Ozone			
D 1149	25 ppm ozone in air by volume, 20% strain 38EC " 1EC (100EF " 2EF), 48 h, mounting procedure D 518, Procedure A	No Cracks	No Cracks	No Cracks
	Adhesion			
D 429, B	Bond made during vulcanization, kg/m (lbs/in.)	714 (40)	714 (40)	714 (40)
	**Low Temperature Test			
	Bearing or sample preparation 96 h @ -29EC " 1EC (-20EF " 2EF), axial load 3,450 kPa (500 psi) and strain of 20% "T"* Test Recorded shear resistance after 1 h (Min.) at 25% shear strain kPa (psi) shall not exceed	207 (30)	276 (40)	345 (50)

* Effective rubber thickness.

** Unless otherwise specified, the Low Temperature Test will be waived.

TABLE B

ASTM Standard	Physical Properties	50 Duro	60 Duro	70 Duro
	Hardness ASTM D 2240	50 " 5	60 " 5	70 " 5
	Tensile strength, Min. (psi)	(2500)	(2500)	(2500)
	ASTM D 412 kPa	17,240	17,240	17,240
	Ultimate elongation, Min. %	400	350	350
	Heat Resistance			
D 573	Change in durometer hardness, max. Points	+ 15	+ 15	+ 15
70 hr.	Change in tensile strength, max. %	-15	-15	-15
@ (100EC)	Change in ultimate elongation, max. %	- 40	-40	-40
212EF	Compression Set			
D 395 Method B	22 h @ 100EC (212EF), max. %	35	35	35
	Ozone			
D 1149	100 ppm ozone in air by volume, 20% strain 38EC " 1EC (100EF " 2EF), 100 h, mounting procedure D 518, Procedure A	No Cracks	No Cracks	No Cracks
	Adhesion			
D 429, B	Bond made during vulcanization, kg/m (lb/in.)	714 (40)	714 (40)	714 (40)
	**Low Temperature Test			
	Bearing or sample preparation 96 h @ -29EC " 1EC (-20EF " 2EF), axial load 3,450 kPa (500 psi) and strain of 20% "T"* Test Recorded shear resistance after 1 h (Min.) at 25% shear strain kPa (psi) shall not exceed	345 (50)	517 (75)	690 (100)

* Effective rubber thickness.

** Unless otherwise specified, the Low Temperature Test will be waived.

Unless otherwise specified, laminates shall be rolled mild steel sheets in accordance with ASTM A 36 or ASTM A 570, grade 36.

(c) Manufacturing Requirements. Plain bearings may be molded individually, cut from previously molded strips or slabs, or extruded and cut to length. Cut edges shall be at least as smooth as ANSI B 46.1 No. 250 finish. Unless otherwise shown on the plans, all components of a laminated bearing shall be molded together into an integral unit. Edges of the nonelastic laminations shall be covered by a minimum of 3 mm (1/8 in.) of elastomer except at laminate restraining devices and around holes that shall be entirely closed on the finished structure. Air bubbles within the elastomeric material shall be cause for rejection.

Each bearing pad shall be marked permanently to show the manufacturer and the month and year of fabrication.

220 **(d) Appearance and Dimensions.** The class for finish and appearance, and flash tolerance, shall be RMA-F3-T.063 for molded bearings and RMA-F2 for extruded bearings in accordance with the requirements of the Rubber Handbook published by the Rubber Manufacturer's Association, Inc.

The permissible variation from the dimensions and configuration required by the plans for both plain and laminated bearings shall be as follows:

Overall Vertical Dimensions
Average Total Thickness 32 mm (1 1/4 in.)
or less..... 0, + 3.2 mm (-0, + 1/8 in.)
Average Total Thickness Over 32 mm
(1 1/4 in.)..... 0, + 6.4 mm (-0, + 1/4 in.)
230 Overall Horizontal Dimensions.....-3.2 mm, + 6.4 mm (-1/8 in., + 1/4 in.)
Thickness of Individual Layers Elastomer
(Laminated Bearings Only)..... -1.6 mm, + 1.6 mm (-1/16 in., + 1/16 in.)
Variations from a Plane Parallel to the Theoretical Surface
Top..... 3.2 mm (1/8 in.)
Sides 6.4 mm (1/4 in.)
Individual Non-Elastic Laminates
(As determined by measurements at the
edges of the bearing)..... 3.2 mm (1/8 in.)
240 Position of Exposed Connection Members 3.2 mm (1/8 in.)
Edge Cover of Embedded Laminates or
Connection Members 0, + 3.2 mm (-0, + 1/8 in.)
Size of Holes, Slots, or Inserts 0, + 3.2 mm (-0, + 1/8 in.)
Position of Holes, Slots, or Inserts 0, + 3.2 mm (-0, + 1/8 in.)
Thickness of Non-Elastic
Laminates..... -0.8, + 1.6 mm (-1/32 in., + 1/16 in.)

250 **(e) Quality Assurance.** The mechanical properties of the finished bearing shall be determined by laboratory test by the manufacturer. The following values shall be used for control of laboratory testing of full size bearings:

1. Compressive strain of any layer of an elastomeric bearing shall not exceed 7% at 5.5 MPa (800 psi) average unit pressure or at the design dead load plus live load pressure if so indicated on the plans.

2. The shear resistance of the bearing shall not exceed 207 kPa (30 psi) for 50 durometer, 276 kPa (40 psi) for 60 durometer, or 345 kPa (50 psi) for 70 durometer, Table A compounds; nor 345 kPa (50 psi) for 50 durometer, 517 kPa (75 psi) for 60 durometer, or 758 kPa (110 psi) for 70 durometer, Table B compounds at 25% strain of the total effective rubber thickness after an extended four day ambient temperature of -29EC (-20EF). Unless otherwise specified, the shear resistance test will be waived.

(f) Certification. Material furnished under this specification shall be covered by a type B certification in accordance with 916. In addition, one bearing pad from each type to be furnished for the structure will be required for laboratory testing. However, when shapes A and B of any type are required, only shape A need be furnished for testing. The material may be sampled prior to shipment to the project, provided suitable arrangements can be made through the Division of Materials and Tests. Materials not previously sampled and approved for use shall be sampled after delivery to the project. Samples shall be furnished at least 30 days before date of use.

SECTION 916 – MATERIALS CERTIFICATIONS

916.01 General. Materials certifications will be required for certain materials in accordance with various sections of these specifications and other contract documents. Unless otherwise specified or directed, one copy of each certification shall be submitted prior to use of the material. All certifications shall be signed by a person having legal authority to bind the company preparing the certification.

The contract number, name of the contractor, destination to which the material covered by the certification is consigned, and name and quantity of material represented shall be shown on all copies of the certification. Identifying information such as alloy, grade, type, class, or other similar designation shall also be shown when applicable.

Any material received on the project for which certification has been furnished may be sampled and tested. If the results of the tests are in disagreement with the certification, the test results shall prevail and further acceptance by certification from the manufacturer of the material concerned may be suspended.

916.02 Types of Certifications. Certifications shall be type A, type B, type C, type D, or as required under other types. When specified, the type of certification provided for a material shall be in accordance with the Frequency Manual except as otherwise specified. Specific information and test results required in type A, type B, and other types of certifications will be listed in the material specifications. Sample forms for type A, type B, type C, and type D certifications are shown in 916.03. Sample forms for other type certifications are shown in 916.03 or ITM 804.

30 **(a) Type A.** Type A certification shall be prepared by the manufacturer. It shall consist of a certified copy of a laboratory report which lists results of the specified tests and shall certify that the materials furnished comply with the specifications. The applicable specification shall be referred to in the certification. The tests may be conducted in the laboratory of the manufacturer or in another qualified laboratory. Such tests shall have been conducted on samples obtained from the lot or lots of material in the shipment.

40 **(b) Type B.** Type B certification shall be prepared by the manufacturer. It shall show the limits of test values for the specified tests and shall certify that the materials furnished comply with the specifications. The applicable specification shall be referred to in the certification. The tests may be conducted in the laboratory of the manufacturer or in another qualified laboratory.

(c) Type C. Type C certification shall be prepared by the manufacturer and shall certify that the materials furnished are in accordance with the specifications. The applicable specification shall be referred to in the certification.

50 **(d) Type D.** Type D certification shall be prepared by the Contractor and shall certify that the materials furnished are in accordance with the specifications. The applicable specification shall be referred to in the certification. A Type D certification shall be used for product identification. It may be required to certify that the material is in accordance with minimum trade standards.

(e) Other Types. Types of certifications other than type A, B, C, and D are specified for selected materials. The requirements for a certification are described in the material's specification.

(f) Requirements for Small Quantities of Materials. Where circumstances warrant and previously approved material is not available, small quantities may be accepted either by a type D certification or by an affidavit from the supplier stating that the material offered is equal to that specified.

60 **(g) Buy American Requirement.** All steel products used in the contract shall be certified to be in accordance with 106.01(a).

916.03 Sample Forms.

(a) For Buy American Requirement.

BUY AMERICAN CERTIFICATION

70 In accordance with Indiana Department of Transportation Specification 106.01(a), I hereby certify that all steel products incorporated in Contract No. _____ were produced and manufactured in the United States of America or territories subject to its jurisdiction.

Date

CONTRACTOR

SIGNATURE

80 **(b) Sample Type A Certification Form.**

INDIANA DEPARTMENT OF TRANSPORTATION

TYPE A CERTIFICATE OF COMPLIANCE

CONTRACT NUMBER _____

PROJECT NUMBER _____

90 CONTRACTOR'S NAME _____

MANUFACTURER'S NAME _____

B/L or INVOICE NUMBER _____

MATERIAL DESTINATION _____

This is to certify that for the contract described above, the materials supplied are as follows:

100

****MATERIAL NAME**

QUANTITY

***Conform to: _____

110 The materials listed above comply with the following Test Methods and are within the acceptable limits of said Test Methods:

TEST METHOD	LIMITS OF TEST VALUE	ACTUAL TEST RESULTS
_____	_____	_____
_____	_____	_____
_____	_____	_____

120 _____
Date Company of Manufacture

* Signature of Company Official/Title

- * This Certification shall be prepared by the manufacturer of the material being supplied for this contract.
- ** Identifying information such as Alloy, Grade, Type, Class, or other similar designation shall also be shown when appropriate.
- *** Applicable material specification reference shall be listed.

130 **(c) Sample Type B Certification Form.**

INDIANA DEPARTMENT OF TRANSPORTATION

TYPE B CERTIFICATE OF COMPLIANCE

CONTRACT NUMBER_____

PROJECT NUMBER _____

140 CONTRACTOR'S NAME _____

MANUFACTURER'S NAME _____

B/L or INVOICE NUMBER _____

MATERIAL DESTINATION _____

150 This is to certify that for the contract described above, the materials supplied are as follows:

**MATERIAL NAME	QUANTITY
_____	_____
_____	_____

***Conform to:_____

160 The materials listed above comply with the following Test Methods and are within the acceptable limits of said Test Methods:

TEST METHOD	LIMITS OF TEST VALUE
_____	_____
_____	_____

170 _____
Date Company of Manufacture

Signature of Company Official/Title

- * This Certification shall be prepared by the manufacturer of the material being supplied for this contract.
- ** Identifying information such as Alloy, Grade, Type, Class, or other similar designation shall also be shown when appropriate.
- *** Applicable material specification reference shall be listed.

180 **(d) Sample Type C Certification Form.**

CONTRACT NUMBER_____

PROJECT NUMBER _____

CONTRACTOR'S NAME_____

MANUFACTURER'S NAME_____

190 B/L or INVOICE NUMBER_____

MATERIAL DESTINATION_____

This is to certify that for the contract described above, the materials supplied are as follows:

****MATERIAL NAME**

QUANTITY

200

_____	_____
_____	_____

***Conform to: _____

_____	_____
Date	Company of Manufacture

* Signature of Company Official/Title

210

- * This Certification shall be prepared by the manufacturer of the material being supplied for this contract.
- ** Identifying information such as Alloy, Grade, Type, Class, or other similar designation shall also be shown when appropriate.
- *** Applicable material specification reference shall be listed.

(e) Sample Type D Certification Form.

CONTRACT NUMBER _____

PROJECT NUMBER _____

220

MANUFACTURER'S NAME _____

MATERIAL DESTINATION _____

This is to certify that for the contract described above, the materials supplied are as follows:

****MATERIAL NAME**

QUANTITY

230

_____	_____
_____	_____

*** Is in accordance with: _____

_____	_____
Date	Contractor

* Signature of Contractor Official/Title

240

- * This certification shall be prepared by the Contractor.
- ** Identifying information such as Alloy, Grade, Class, or other similar designation shall be shown when appropriate.
- *** Applicable material specification reference shall be listed. Otherwise, a statement shall be provided that the material supplied is in accordance with minimum trade standards.

(f) Sample Asbestos Exclusion Letter. Prior to acceptance of work and final payment, the Contractor shall submit to the Engineer for each building or bridge, on the Contractor's letterhead, a signed, dated copy of the following:

ASBESTOS EXCLUSION LETTER

Date

work address of Engineer for
Indiana Department of Transportation

Att.: _____
Name, Engineer

Re: Asbestos Exclusion
Location/Description
Contract Number
Bridge Structure Number
Contractor's Name

Dear Engineer:

I hereby certify that to the best of my knowledge no asbestos containing material was used as a building material in this project.

Very truly yours,

signature of Contractor official

title of Contractor official

SECTION 917 – QUALITY ASSURANCE AGGREGATE CERTIFICATION

917.01 General Requirements. An aggregate source will be authorized to ship products in the status of a Certified Aggregate Producer who is in accordance with the required standards of ITM 211. This will consist of a program which will require the aggregate source to make a commitment to product quality management. Approval to participate in the program will be based on the following criteria.

- (a) existence of suitable materials in the deposit being mined;
- (b) facilities capable of consistently processing uniform materials in accordance with the specification requirements; and

- (c) a source Quality Control Plan which will ensure that the mineral aggregates have a 95% assurance of being in accordance with the Department's quality and uniformity requirements.

20 Specific details of this program are contained in ITM 211. Sampling and testing details are found in the Inspection and Sampling Procedures for Fine and Coarse Aggregates manual. A Certified Aggregate Producer shall operate in accordance with the requirements of both publications.

917.02 Quality Control Plan. An aggregate source will not be approved as a Certified Aggregate Producer until it has prepared a Quality Control Plan and the plan has been approved. The plan shall encompass all details of production starting with the extraction of the indigenous raw materials and concluding with material shipped from the plant. The Quality Control Plan shall be prepared in accordance with the requirements of ITM 211.

30 **917.03 Source Approval Requirements.** The Division of Materials and Tests shall be notified in writing that the aggregate source wants to become a Certified Aggregate Producer. The aggregate source shall identify the specific products for which approval is sought. Such list shall include all of the products to be produced at the source regardless of whether the products are for Department or other uses.

An aggregate source may not be considered for entry into the certification program until the preliminary source investigation has been completed in accordance with Indiana Test Method 203.

40 The following procedure will be used to establish an aggregate source as a Certified Aggregate Producer.

(a) Step 1. The source shall enter the coordinated testing phase of ITM 211. Coordinated testing shall be performed in accordance with ITM 211. During this phase, the producer shall be required to develop a Quality Control Plan to establish demonstrated mean test values and standard deviations.

50 **(b) Step 2.** The aggregate source shall enter the trial phase. The producer shall also operate in accordance with ITM 211 and the Quality Control Plan. The Quality Control Plan shall be refined as may be necessary.

60 **(c) Step 3.** The aggregate source will become an approved Certified Aggregate Producer following satisfactory performance during the trial phase. Achieving such status shall be accompanied by the inherent responsibility to operate within the tenets of ITM 211. The Certified Aggregate Producer shall produce material at a compliance requirement of effectively 95% of the appropriate specifications. The Department will monitor such compliance through the use of periodic in-depth inspections of the production site. Continuing approval is contingent upon the effectiveness of the producer's Quality Control Plan as evidenced by the quality and uniformity of the products which are prepared in accordance with the appropriate specifications and ITM 211.

917.04 Removal from Certified Producer Status. The Division of Materials and Tests will be responsible for the review and removal of an aggregate source from being an approved Certified Aggregate Producer. A Certified Aggregate Producer shall operate so as to avoid a need for the Department to exercise this action. However, removal from Certified Producer status may be necessary for situations such as:

- 70 (a) the statistical probability of the product compliance has fallen below 90%;
- (b) the product has a 90% to 95% probability of compliance but the producer has failed to take corrective action to restore 95% probability;
- (c) the Certified Aggregate Producer has failed to take immediate corrective action relative to deficiencies in the performance of the approved Quality Control Plan;
- 80 (d) evaluation of data has demonstrated an inability of the Certified Aggregate Producer to consistently be in accordance with Department requirements;
- (e) the Certified Aggregate Producer has deliberately shipped aggregate material which is not in accordance with the specifications, or has falsified records; or
- (f) the production site has not been operated in accordance with the Summary of Production or Ledge Quality Results letter.

90 Notice of removal from Certified status will be in written form, will be issued by the Division of Materials and Tests, and will identify the reasons for the removal. Effective immediately upon receipt of such notification, no further aggregate shipments shall be made on a certified basis.

917.05 Appeals. The producer shall have the right to appeal removal from Certified Producer status to the Engineer. The appeal shall be in written form, shall state the reason or reasons on which the appeal is based, and shall be received within 14 calendar days of receipt of the removal notice.