SECTION 900 – MATERIALS DETAILS

SECTION 901 – PCC MATERIALS

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.

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.

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.

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.

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 a QCP in accordance with the applicable requirements of ITM 806. The QCP shall also include 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 _____ 20____".

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 a QCP in accordance with the applicable requirements of ITM 806. The QCP shall also include 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 QCP 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.

(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 _____, 20___."

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.

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.

(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.

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:

Loss on Ignition (LOI), Maximum %	3
Autoclave Expansion or Contraction, Maximum %	0.5
Fineness: Amount retained when wet-sieved on 45 μm 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 μm (No. 325) sieve residue for each sample.

For each 1800 Mg (2,000 t) 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:

a. The 45 μm (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.

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:

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 QCP in accordance with the applicable requirements of ITM 806. The QCP shall ensure the Department of a continuous supply of fly ash complying with the requirements. This QCP will be reviewed to determine its adequacy.

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.

(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.

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.

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 t) 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 μm (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.

3. Documentation. Ground granulated blast furnace slag suppliers requesting approval shall supply the following:

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 ground granulated blast furnace slag suppliers shall furnish a a QCP in accordance with the applicable requirements of ITM 806. The QCP shall ensure the Department of a continuous supply of ground granulated blast furnace slag which is in accordance with the requirements. This QCP will be reviewed to determine its adequacy.

d. Certification:

(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.

(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.

(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.

1. Requirements. The silica fume shall be in accordance with AASHTO M 307 with the following exceptions:

a. Reactivity with cement alkalies shall not be required.

b. The oversize, amount retained on the 45 μm (No. 325) sieve, in accordance with ASTM C 1240, shall be conducted.

c. The oversize, amount retained on the 45 μm (No. 325) sieve, shall not be more than 10%.

d. Accelerated pozzolanic activity index, in accordance with ASTM C 1240, shall be conducted in lieu of strength activity index.

e. The accelerated pozzolanic activity index shall be a minimum of 85% at seven days.

f. The increase of drying shrinkage of mortar bars at 28 days shall be conducted in accordance with ASTM C 1240.

g. The increase of drying shrinkage of mortar bars at 28 days shall not be more than 0.10%

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.

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 requirements identified in AASHTO M 307 shall be reported in addition to the increase of drying shrinkage of mortar bars as well as 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 QCP in accordance with the applicable requirements of ITM 806 shall be submittee. The QCP shall ensure the Department a continuous supply of silica fume complying with the material requirements and calibration procedures. This QCP 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.

901.05 Chemical Anchor Systems. Chemical anchor systems shall be furnished from the Department's list of approved Chemical Anchor Systems. Chemical anchor systems may be added to the approved list by completing the requirements in ITM 806, Procedure F and passing required laboratory testing.

(a) Requirements. Chemical anchor systems shall be in accordance with the following:

1. Chemical anchor systems shall be two part systems which are capable of anchoring deformed steel reinforcing bar and grouting load transfer dowels.

2. Chemically anchored steel reinforcing bar shall be capable of withstanding a tensile load equal to the yield strength of a #22 (#7), grade 400 (60), epoxy coated, deformed steel reinforcing bar.

3. Chemical anchor systems shall be capable of filling the entire annular space between the concrete and the steel reinforcing bar or dowel and remain in place until the chemical anchor is completely cured.

(b) Laboratory Testing. The Department will test chemical anchor systems in accordance with ITM 807.

901.06 PCC Sealer/Healers. PCC sealer/healers shall be furnished from the Department's list of approved PCC Sealer/Healers. PCC sealer/healers may be added to the approved list by completing the requirements in ITM 806, Procedure F and passing required laboratory testing.

(a) Requirements. PCC sealer/healers shall be in accordance with the following:

1. PCC sealer/healers shall be two part systems, capable of sealing and healing cracks in PC pavement.

2. PCC sealer/healers shall be capable of restoring the original integrity of a PCC beam broken in flexure.

3. All four beams used for testing sealer/healers shall break at a location different from the original break or with a flexural strength greater than or equal to 3800 kPa (550 psi).

4. The viscosity of PCC sealer/healers shall be sufficient to penetrate a crack 0.8 mm (1/32 in.) wide and 150 mm (6 in.) in depth.

(b) Laboratory Testing. The Department will test PCC sealer/healers in accordance with ITM 808.

901.07 Rapid Setting Patch Materials. Rapid setting patch materials shall be selected from the Department's list of approved Rapid Setting Patch Materials. A rapid setting patch material may be added to the list by completing the requirements in ITM 806, procedure F.

(a) Normal Weather Mixes. Normal weather rapid setting patch materials shall be used for ambient temperatures of 0 - 30°C (32 - 85°F).

(b) Hot Weather Mixes. Hot weather rapid setting patch materials shall be used for ambient temperatures above 30°C (85°F).

(c) Requirements. Rapid setting patch materials shall be capable of being utilized in patches ranging from 25 mm (1 in.) to full depth without bonding agents, no curing material shall be required, and shall be capable of being surface sealed with an epoxy sealer.

These products shall not contain soluble chlorides as an ingredient of manufacture nor shall they require chemical additives. The color shall be similar to PCC.

They shall be single packaged dry mix requiring only water just prior to mixing. They shall be packaged in 18 - 27 kg (40 - 60 lb) bags with a neat yield of approximately 0.011 m^3 (0.40 yd^3) and shall allow at least a 50% extension, by mass, (weight) with a 10 mm (3/8 in.) or a 13 mm (1/2 in.) round aggregate. The minimum shelf life shall be twelve months.

Mixing shall be conducted with small concrete mixers or with a drill or paddle mixer and shall be suitable for finishing with hand tools.

Rapid setting patch materials shall be in accordance with ASTM C 928 with the following exceptions.

Physical Test	Specification	Requirement
Setting Time	ASTM C 266	
Normal Weather		
Initial at 22°C (72°F)		10-20 min
Final at 22°C (72°F)		12-35 min

Hot Weather		
Initial at 35°C (95°F)		10-20 min
Final at 35°C (95°F)		12-35 min
Compressive Strength, Min.*	AASHTO T 109	22°C (72°F), Normal
1 h		14 MPa (2000 psi)
2 h		21 MPa (3000 psi)
24 h		34.5 MPa (5000 psi)
28 day		55 MPa (8000 psi)
Compressive Strength, Min.*	ASTM C 109	35°C (95°F), Hot
3 h		21 MPa (3000 psi)
24 h		34.5 MPa (5000 psi)
28 days		55 MPa (8000 psi)
Relative Dynamic Modulus	ASTM C 666	
Procedure B 300 cycles		95% Min.
Slant Shear Bond Strength, Min	ASTM C 882	
28 days		17 MPa (2500 psi)
Flexural Strength, 24 h	ASTM C 78	
mortar only		3.5 MPa (500 psi)
mortar - aggregate extension		4.0 MPa (600 psi)
Shrinkage, Max.	ASTM C 157	
28 days		0.03%
Scaling Resistance	ASTM C 157	
5 cycles		0 rating, No scale
25 cycles		0 rating, No scale
50+ cycles		1.5 rating, Lt. Scale

* Material used shall be neat rapid setting patch material mixed in accordance with the manufacturer's installation instructions.

All rapid setting patch materials complying with the specified physical requirements will be subjected to a field performance demonstration. The field performance demonstration will take place as directed. Rapid setting patch materials shall be used to patch a designated site, typical of a standard repair. The site will be evaluated after one year's exposure. Approval will be based on visible signs of distress, such as cracking, crazing, scaling, spalling, wearing, edge fraying, corner cracking, or debonding.

(d) Test Report. Testing shall be performed by a recognized laboratory in accordance with ITM 806. Test reports shall not be more than five years old on January first of the approval year.

SECTION 902 – ASPHALT MATERIALS

902.01 Asphalt. Asphalt is defined as a cementatious 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 asphalt binders shall be supplied by an approved suppler in accordance with ITM 581.

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

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

NOTES 1. Oven temperature tolerance shall be ± 0.5°C.
2. Physical Hardening is performed on a set of asphalt beams according to AASHTO T313, Section 12.1, except the conditioning time is extended to 24 h ± 10 min at 10°C above the minimum performance temperature. The 24 h stiffness and m-value are reported for information purposes only.

1. 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 complete AASHTO M 320 test results for the specific sublot in question plus test values from all other sublots for the parameters being disputed.

If an appeal is accepted, the Department will randomly select two additional sublot samples if available from the lot in question. The additional sublot samples if available and the backup sample will be tested in an AASHTO accredited laboraory 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-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.

AE-90S is a rapid setting, anionic type emulsion for seal coat applications.

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.

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.

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

AE-PMP is a polymerized modified asphalt emulsion intended for use as a prime coat material.

AE-PMT is a polymerized modified asphalt emulsion intended for use as a tack coat material.

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

Characteristic (1) (2)	Test Method	RS-2	HFRS-2	AE-90	AE-90S	AE-T	AE-150	AE-150L	AE-PL	AE-PMT (6)	AE-PMP (6)
Test on Emulsion											
Viscosity, Saybolt Furol at 25°C, min.	AASHTO T 72			50			50				20+
Viscosity, Saybolt Furol at 25°C, max.	AASHTO T 72					100		100	115	100	
Viscosity, Saybolt Furol at 50°C, min.	AASHTO T 72	75	75		50		75				
Viscosity, Saybolt Furol at 50°C, max.	AASHTO T 72	400	400				300				
Demulsibility w/35 mL, 0.02N CaC12, %, min.	AASHTO T 59	50	50		30						
Demulsibility w/50 mL, 0.10N CaC12, %, min.	AASHTO T 59			75		75				25+	25+
Oil Distillate by Distillation, mL/100 g Emul. (3)	AASHTO T 59	4.0	4.0	4.0	3.0	4.0	7.0	7.0	3.0	3.0	3.0
Residue by Distillation, %, min.	AASHTO T 59	68	68	68	65 (5)	54	68	60	30		
Residue by Distillation, %, max.	AASHTO T 59					62		65			
Sieve Test, %, max.	AASHTO T 59	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Penetrating Ability, mm, min.	902.02(w)								6		
Stone Coating Test, %	902.02(t)3a			90			90	90			
Settlement, %, max.	AASHTO T 59	5	5	5							
Storage Stability, %, max.	AASHTO T 59				1						
Asphalt Content by Distillation at 204°C, %, min.										54	45
Asphalt Content by Distillation at 204°C, %, max.										62	
Tests on Residue											
Penetration (0.1 mm) at 25°C, 100g, 5 s, min. (4)	AASHTO T 49	100	100	100	90	50				50	300+
Penetration (0.1 mm) at 25°C, 100g, 5 s, max. (4)	AASHTO T 49	200	200	200	150	200				200	
Penetration (0.1 mm) at 25°C, 50g, 5 s, min. (4)	AASHTO T 49						100	100			
Penetration (0.1 mm) at 25°C, 50g, 5 s, max. (4)	AASHTO T 49						300	300			
Ductility at 25°C, mm, min.	AASHTO T 51	400	400	400		400					
Solubility in Org. Sol., %, min.	AASHTO T 44	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5
Float Test at 50°C, s, max. (4)	AASHTO T 50										
Float Test at 60°C, s, min. (4)	AASHTO T 50		1200	1200	1200	1200	1200	1200			
Force Ratio	AASHTO T 300				0.3						
Elastic Recovery, at 4°C	AASHTO T 301				58						
Polymer Content by Infrared										1.5+	1.5+

NOTES: (1) Broken samples or samples more than 10 days old will not be tested.
(2) Combined percentage of the residue and oil distillate by distillation shall be at least 70% (note the different units – ml for oil and % for residue).
(3) Oil distillate shall be in accordance with ASTM D 396, table 1, grade no. 1.
(4) The Engineer may waive the test.
(5) Maximum temperature to be held for 15 minutes 200 ± 5°C.
(6) Asphalt shall be polymerized prior to emulsification.

(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.), °C[4]	38+	66+	66+	66+
Kinematic Viscosity at 60°C (cSt.)[2]	70-140	250-500	800-1600	3000-6000
Saybolt-Furol Viscosity at 50°C (s)	60-120			
Saybolt-Furol Viscosity at 60°C (s)		125-250		
Saybolt-Furol Viscosity at 83°C (s)			100-200	300-600
Distillation[1]				
Distillate (% of total distillate to 360°C MC-70 @ 225°C):				
to 225°C	0-20	0-10		
to 260°C	20-60	15-55	35+	15+
to 316°C	65-90	60-87	45-80	15-75
Residue from distillation to 360°C (volume % by difference)	55+	67+	75+	80+
Tests on Residue from Distillation:[1]				
Penetration, 25°C, 100 g, 5 s - (0.1 mm)				
(without additive)	120-250	120-250	120-250	120-250
(with additive)	120-300	120-300	120-300	120-300
Ductility, 25°C (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 25°C is less than 100, the material will be acceptable if its ductility at 16°C is 100+.
(4) Flash point by Cleveland Open Cup may be used for products having a flash point greater than 80°C.

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), (°C)	66+	79+	93+	107+
Kinematic Viscosity at 60°C (cSt)[2]	70-140	250-500	800-1600	3000-6000
Saybolt-Furol Viscosity at 50°C (s) Saybolt-Furol Viscosity at 60°C (s) Saybolt-Furol Viscosity at 83°C (s)	60-120	125-250	100-200	300-600
Distillation[1] Total Distillate to 360°C (% by volume) Float Test of Distillation Residue at 50°C (s)	10-30 20-100	4-20 25-110	2-12 50-140	5 75-200
Ductility of Asphalt Residue at 25°C (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.

(d) Utility Asphalt. The asphalts shall be uniform in character and shall not foam when heated to 177°C (350°F). Utility asphalts shall be in accordance with the following:

Characteristics/Grades	UA-I	UA-II	UA-III
Softening Point (Ring & Ball), °C	46-63	63-85	79.5-96
Penetration of Original Samples[1] (0.1 mm) at 4°C, 200 g, 60, s Min. at 25°C, 100 g, 5 s at 46°C, 50 g, 5 s	 10 50-100 100 Min.	 10 25-45 130 Max.	 10 15-35 90 Max.
Ductility @ 25°C, 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), °C, Min.[1]	225	225	225
Penetration of Residue from Thin Film Oven Test, 25°C, 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), °C	93	110
Penetration of Original Samples (0.1 mm) at 4°C, 200 g, 60 s, Min. at 25°C, 100 g, 5 s	 20 35[1]	
Solubility In Organic Solvents, %	99.0	
Flash Point (Cleveland Open Cup), °C	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.

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

(a) Sampling Bituminous Materials..... AASHTO 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 at one of the following:

   a. bulk storage tanks from sampling valves located in the tank or line and asphalt plant storage tanks from sampling valves located in the tank

   b. transports from sampling valves

   c. distributors from approved 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 toluene ..... AASHTO 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)

1. When the flash point is higher than 79°C (175°F), "Flash and Fire Points by Cleveland Open Cup" ..... AASHTO T 48

2. When the flash point is 79°C (175°F) or lower, "Flash Point with Tagliabue Open Cup" ..... AASHTO T 79

(g) Softening Point of Bituminous Materials,
Ring and Ball..... AASHTO T 53

(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

(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

(n) Distillation of Cutback Asphaltic Products, except the
length of condenser tube may be 400 mm $\pm$ 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

(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 Emulsions..... AASHTO 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 46°C (115°F) water bath for 5 min to bring the contents of the jar to a temperature of approximately 38°C (100°F). 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 121°C (250°F) in a laboratory oven for 2 h; stirred and cooled to 92.5°C (200°F). 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:

(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 request..... 10 parts

(3) Water ..... 3 parts

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

c. Ruler or other measuring device

d. Timing device readable in seconds

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:

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 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

(z) Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus ..... AASHTO T 316

(aa) Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer ..... AASHTO T 315

(bb) Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel ..... AASHTO R 28

(cc) Determining the Flexural Creep Stiffness of Asphalt Binder Using the Bending Beam Rheometer ... AASHTO T 313

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 °C (°F)	
	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 μm (No. 40) sieve
Fine Sand	425 μm (No. 40) to 75 μm (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:

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 μm (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 μm (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 Aggregates. Aggregates shall consist of natural or manufactured materials produced from but not limited to limestone, dolomite, gravels, sandstones, steel furnace slag (SF), air-cooled blast furnace slag (ACBF), granulated blast furnace (GBF), wet bottom boiler slag, or other geologic rock types approved by the Engineer.

A source will not 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 quality and classification of the aggregates in accordance with ITM 203.

Two types of samples are required for the preliminary investigation; ledge samples for crushed stone sources and production samples for crushed stone, natural sand and gravel, and slag sources.

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

Production samples will be obtained from stockpiles of finished materials.

Aggregates, except those used for precast concrete units or fine aggregates used for snow and ice abrasive, shall be supplied by a Certified Aggregate Producer in accordance with 917. Structure backfill may be obtained from a non-CAPP source in accordance with 211.02.

Dolomite aggregates are defined as carbonate rock containing at least 10.3% elemental magnesium when tested in accordance with ITM 205.

Polish resistant aggregates are defined as those aggregates in accordance with ITM 214. Aggregates meeting these requirements will be maintained on the Department's list of approved Polish Resistant Aggregates.

Sandstone aggregates shall only be used in HMA surface mixtures. Sandstone aggregates are 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. The Materials and Tests Division will determine identification of sandstone.

Steel furnace (SF) slag shall only be used in aggregate shoulders, HMA surface mixtures, dumped riprap, and snow and ice abrasives.

Adjustments in mass (weight) shall be made to compensate for the difference in specific gravity of slag compared to natural aggregate when payment is on a mass (weight) basis. The following typical values for specific gravity will be used: natural aggregate both fine and coarse, 2.6; ACBF slag coarse aggregate, 2.3; ACBF slag fine aggregate, 2.6; GBF slag fine aggregate, 2.1; and SF slag both fine and coarse, 3.4. The contract quantity shall not be adjusted on any pay item less than 500 Mg (500 t).

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 contract quantities will be determined by multiplying the accepted quantity of megagrams (tons) by 2.6 divided by the specific gravity of the slag.

At time of use, aggregates shall be free from lumps or crusts of hardened or frozen materials.

904.02 Fine Aggregates. Fine aggregates are defined as 100% passing the 9.5 mm (3/8 in.) sieve and a minimum of 80% passing the 4.75 mm (No.4) sieve. Characteristics of fine aggregates are as follows:

Characteristic	PCC	HMA
Physical		
Organic Impurities, AASHTO T 21, lighter than or equal to, Color Standard (Note 1)	3	
Acid Insoluble, ITM 202 (Note 2)		40
Soundness		
Freeze and Thaw, AASHTO T 103, Method A, % Max. (Note 3)	10%	10%
Brine Freeze-and-Thaw, ITM 209, % Max. (Note 3).....	12%	12%
Sodium Sulfate Soundness, AASHTO T 104, % Max. (Note 3)	10%	10%

NOTES:
1. 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.
2. For ACBF or GBF slag sands, the minimum acid insoluble content shall be 25%. Acid insoluble requirements shall not apply to crushed limestone or dolomite sands.
3. AASHTO T 104 and ITM 209 may be run at the option of the Engineer, in-lieu of AASHTO T 103.

(a) For Portland Cement Concrete. Fine aggregate for use in PCCP or bridge decks shall be natural sand. Fine aggregate for other PCC shall be natural sand or crushed limestone, dolomite, gravel, or ACBF.

Natural sand which has been used as foundry sand when tested in accordance with ITM 215, and 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. When foundry sand is used, the precast concrete manufacturer shall maintain a copy of the Waste Classification issued by IDEM and an indemnification statement shall accompany the precast items to each contract.

(b) For HMA Mixtures. Fine aggregate for use in HMA shall be natural sand or crushed limestone, dolomite, gravel, or ACBF. SF sand may be used only when the coarse aggregate is SF. The amount of crushed limestone sand shall not exceed 20% of the total aggregate used in HMA surface mixtures with ESAL equal to or greater than 3,000,000, except limestone sands manufactured from aggregates on the Department's list of approved Polish Resistant Aggregates will not be limited. If soundness testing cannot be conducted, the aggregate shall come from a Category I source in accordance with ITM 203.

The fine aggregate angularity value of the total blended aggregate material from the fine and coarse aggregates, and recycled materials shall meet or exceed the minimum values for the appropriate ESAL category and position within the pavement structure as follows:

FINE AGGREGATE ANGULARITY		
TRAFFIC, ESAL	DEPTH FROM SURFACE	
	≤ 100 mm	> 100 mm
< 300,000		
300,000 to < 3,000,000	40	40
3,000,000 to < 10,000,000	45	40
10,000,000 to < 30,000,000	45	40
≥ 30,000,000	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 as follows:

CLAY CONTENT	
TRAFFIC, ESAL	SAND EQUIVALENT, MINIMUM
< 300,000	40
300,000 to < 3,000,000	40
3,000,000 to < 10,000,000	45
10,000,000 to < 30,000,000	45
≥ 30,000,000	50

Clay Content, Sand Equivalency .....AASHTO T 176

(c) For Pneumatically Placed Mortar. Fine aggregate shall be natural sand suitable for use with a pneumatic cement gun. Fine aggregate shall be size No. 15, or size PP in accordance with 904.02(g), or an approved gradation from a CAPP source.

(d) Mortar Sand. Fine aggregate for mortar shall consist of uniformly graded natural sand in accordance with gradation requirements of 904.02(g) for size No. 15 or an approved gradation from a CAPP source.

(e) Blank.

(f) Snow and Ice Abrasives. Snow and ice abrasives shall be fine aggregates or cinders in accordance with the gradation requirements of 904.02(g) for size S&I.

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 904.01.

(g) Sizes of Fine Aggregates.

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

Note 1: 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:

Acid Insoluble Content ..... ITM 202
*Amount of Material Finer than
75 μm (No. 200) sieve ..... AASHTO T 11
Brine Freeze-and-Thaw Soundness ..... ITM 209
Control Procedures for Classification of Aggregates ..... ITM 203
Mortar Strength ..... AASHTO T 71
Organic Impurities ..... AASHTO T 21
Sampling Aggregates ..... AASHTO T 2
Sampling Stockpiled Aggregates ..... ITM 207
*Sieve Analysis of Aggregate ..... AASHTO T 27
*Soundness ..... AASHTO T 103, T 104
Specific Gravity and Absorption, Fine Aggregate ..... AASHTO T 84

*Except as noted in 904.06.

904.03 Coarse Aggregates. Coarse aggregates are defined as having a minimum of 20% retained on the 4.75 mm (No.4) sieve. Coarse aggregates shall not contain adherent fines that are detrimental to the end product as defined in ITM 211.

The coarse aggregate shall comply with the quality requirements and the additional requirements in accordance with 904.03(a). However, coarse aggregate may be rejected based on previous performance service records. Class AP 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 of aggregate products to improve the quality classification of the finished product will not be permitted.

(a) Classification of Aggregates.

Characteristic Classes	AP	A	B	C	D	E	F
Quality Requirements							
Freeze-and-Thaw Beam Expansion, % Max. (Note 1)	.060						
Los Angeles Abrasion, %, Max. (Note 2)	40.0	40.0	40.0	45.0	45.0	50.0	
Sodium Sulfate Soundness, %, Max. (Note 3)	12.0	12.0	12.0	16.0	16.0	20.0	25.0
Brine Freeze-and-Thaw Soundness, % Max. (Note 4)	30	30	30	40	40	50	60
Absorption, %, Max. (Note 5)	5.0	5.0	5.0	5.0			
Additional Requirements							
Deleterious, %, Max.							
Clay Lumps and Friable Particles	1.0	1.0	1.0	2.0	4.0		
Non-Durable (Note 6)	4.0	4.0	4.0	6.0	8.0		
Coke				(See	Note 7)		
Iron				(See	Note 7)		
Chert (Note 8)	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 9)							
Asphalt Seal Coats		70.0	70.0				
Compacted Aggregates		20.0	20.0	20.0	20.0		

NOTES: 1. Freeze-and-thaw beam expansion shall be tested and retested in accordance with ITM 210.

2. Los Angeles abrasion requirements shall not apply to BF.

3. 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.

4. Brine freeze-and-thaw soundness requirements are subject to the conditions stated in Note 3.

5. Absorption requirements apply only to aggregates used in PCC and HMA mixtures except they shall not apply to BF. 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 PCC or HMA mixtures. Materials having absorption values between 5.0 and 6.0 that pass AP testing may be used in PCC. If variations in absorption preclude satisfactory production of PCC or HMA mixtures, independent stockpiles of materials will be sampled, tested, and approved prior to use.

6. 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.

7. ACBF and SF coarse aggregate shall be free of objectionable amounts of coke and iron.

8. 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 2 through 8, 43, 53, and 73, and on the total mass (weight) of material retained on the 4.75 mm (No. 4) sieve for sizes 9, 11, 12, and 91.

9. Crushed particle requirements apply to gravel coarse aggregates used in compacted aggregates, and seal coats except seal coats used on shoulders. Determination of crushed particles shall be made from the weight (mass) of material retained on the 4.75 mm (No. 4) sieve in accordance with ASTM D 5821.

(b) Coarse Aggregate Angularity. The coarse aggregate angularity (CAA) value of the total blended aggregate material, including recycled materials, shall meet or exceed the minimum values for the appropriate ESAL category and position within the pavement structure as follows:

COARSE AGGREGATE ANGULARITY		
TRAFFIC, ESAL	DEPTH FROM SURFACE	
	≤ 100 mm (4 in.)	> 100 mm (4 in.)
< 300,000	55	
300,000 to < 3,000,000	75	50
3,000,000 to < 10,000,000	85/80*	60
10,000,000 to < 30,000,000	95/90*	80/75*
≥ 30,000,000	100/100*	100/100*

* Denotes two faced crush requirements

Coarse Aggregate Angularity ..... ASTM D 5821

(c) Flat and Elongated. The coarse aggregate shall contain 10% or less flat and elongated particles. A flat and elongated piece is defined as a particle having a ratio of length to thickness greater than five. Determination of flat and elongated particles shall be made from the weight (mass) of material retained on the 9.5 mm (3/8 in.) sieve and each sieve size greater than the 9.5 mm (3/8 in.) sieve.

Flat and Elongated ..... ASTM D 4791

(d) Surface Aggregate Requirements. The surface mixture aggregate selection shall be based on the ESAL category as follows:

Coarse Aggregate Type	Traffic ESAL		
	< 3,000,000	< 10,000,000	≥ 10,000,000
Air-Cooled Blast Furnace Slag	Yes	Yes	Yes
Steel Furnace Slag	Yes	Yes	Yes
Sandstone	Yes	Yes	Yes
Crushed Dolomite	Yes	Yes	Note 1
Polished Resistant Aggregates	Yes	Yes	Note 1
Crushed Stone	Yes	No	No
Gravel	Yes	No	No

Note 1. Polish resistant aggregates or crushed dolomite may be used when blended with ACBF or sandstone but cannot exceed 50% of the coarse aggregate by mass (weight), or cannot exceed 40% of the coarse aggregate by mass (weight) when blended with steel furnace slag.

(e) Sizes of Coarse Aggregates.

Sieve Sizes	COARSE AGGREGATE SIZES (PERCENTS PASSING)									
	COARSE GRADED								DENSE GRADED	
	2	5	8	9	11	12	43(1)	91	53(1)	73(1)
100 mm (4 in.)										
90 mm (3 1/2 in.)										
63 mm (2 1/2 in.)	100									
50 mm (2 in.)	80-100									
37.5 mm (1 1/2 in.)		100					100		100	
25 mm (1 in.)	0-25	85-98	100				70-90	100	80-100	100
19 mm (3/4 in.)	0-10	60-85	75-95	100			50-70		70-90	90-100
12.5 mm (1/2 in.)	0-7	30-60	40-70	60-85	100	100	35-50		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	20-40		35-60	35-60
2.36 mm (No. 8)		0-10	0-10	0-10	0-10	0-35	15-35		25-50	
600 μm (No. 30)						0-4	5-20		12-30	12-30
75 μm (No. 200)(2)							0-6.0		5.0-10.0(4)	5.0-12.0
Decant (PCC) (3)		0-1.5	0-1.5	0-1.5	0-1.5	0-1.5		0-1.5		
Decant (Non-PCC)	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 μm (No. 200) sieve shall not exceed 2/3 the fraction passing the 600 μm (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 μm (No. 200) sieve as determined by AASHTO T 11 and T 27.
3. Decant may be 0-2.5 for stone and slag
4. When slag is used for separation layers as defined in 302.01, the total amount passing the 75 μm (No. 200) sieve shall be 10.0 to 12.0.

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

Abrasion ..... AASHTO T 96
* Amount of Material finer than 75 μm (No. 200) Sieve ..... AASHTO 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 ..... ASTM D 5821
Dolomite Aggregates ..... ITM 205
Flat and Elongated Particles ..... ASTM D 4791
Freeze-and-Thaw Beam Expansion ..... ITM 210
* Lightweight Pieces in Aggregates ..... AASHTO T 113
Polished Resistant Aggregates ..... ITM 214
* 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
Unit Weight and Voids in Aggregates ..... AASHTO T 19

*Except as noted in 904.06.

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

(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.

(b) Grouted Riprap. Grouted riprap material shall be in accordance with Dumped riprap or Revetment riprap.

(c) Revetment, Class 1, and Class 2 Riprap. The material shall be coarse aggregate, Class F or higher. Gradation shall be in accordance with 904.04(e).

(d) Uniform Riprap. The material shall be coarse aggregate, Class F or higher in accordance with 904.03(a). Gradation shall be in accordance with 904.04(e). Either type A or type B may be utilized.

(e) Sizes of Riprap.

GRADATION REQUIREMENTS					
Percent Smaller					
Size, mm (in.)	Revetment	Class 1	Class 2	Uniform A	Uniform B
750 (30)			100		
600 (24)		100	85-100		
450 (18)	100	85-100	60-80		
300 (12)	90-100	35-50	20-40		
200 (8)				100	
150 (6)	20-40	10-30	0-20	35-80	95-100
75 (3)	0-10	0-10	0-10		35-80
25 (1)				0-20	0-20
Depth of Riprap, minimum	450 mm (18 in.)	600 mm (24 in.)	750 mm (30 in.)		

The maximum dimension of individual pieces shall not be greater than three times the minimum dimension. The riprap will be visually inspected for size, shape, and consistency.

904.05 Structure Backfill. The material shall be of acceptable quality, free from large or frozen lumps, wood, or other extraneous matter. It shall consist of suitable sand, gravel, crushed stone, ACBF, or GBF. Coarse aggregate used for backfilling end bents on beam structures shall be No. 8 or No. 9 crushed stone or BF slag, Class D or higher, in accordance with 904. Structure backfill shall be in accordance with one of the following gradations.

Sieve Sizes	NOMINAL SIZES AND PERCENTS PASSING					
	50 mm (2 in.)	37.5 mm (1 1/2 in.)	25.0 mm (1 in.)	12.5 mm (1/2 in.)	4.75 mm (No. 4)	600 μm (No. 30)
63 mm (2 1/2 in.)	100					
50 mm (2 in.)	90-100	100				
37.5 mm (1 1/2 in.)	70-100	90-100	100	100		
25.0 mm (1 in.)	55-95	70-100	85-100			
19.0 mm (3/4 in.)	45-90	55-95	70-100			
12.5 mm (1/2 in.)	35-85	40-90	55-95	85-100	100	100
4.75 mm (No. 4)	20-65	20-70	25-75	45-85	90-100	
2.36 mm (No. 8)	10-50	10-55	15-60	25-75	75-100	
600 μm (No. 30)	3-35	3-35	3-35	5-45	15-70	70-100
75 μm (No. 200)	0-8.0	0-8.0	0-8.0	0-8.0	0-8.0	0-8.0

904.06 Exceptions to AASHTO Standard Methods.

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

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

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 balance shall be a Class G2 general purpose balance in accordance with AASHTO M 231.

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

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

Aggregate Size	Minimum Mass (Weight) of Test Sample
No. 2	11.3 kg (25 lb)
No. 5, 8, 43, 53, 73, and 91	6-8 kg (13-18 lb)
No. 9	4-6 kg (9-13 lb)
* Subbase	4-6 kg (9-13 lb)
* B Borrow	4-6 kg (9-13 lb)

* The minimum mass (weight) of the test sample for 4.75 mm (No. 4) and 600 μm (No. 30) B borrow shall be 300 grams (10 oz).

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

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

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.

3. In the case of ledge rock, modify sections 3.3 and 6.2 of AASHTO T 103 and AASHTO 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 AASHTO T 103 and section 10 of AASHTO 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.

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.

905.04 Precast 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 the fine aggregates shall be in accordance with 904.02(a) and the coarse aggregates, class A or higher, shall be in accordance with 904.03. 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/m^3 (12 lb/cu ft) for an average of three units.

905.05 Detectable Warning Elements. Detectable warning bricks used in sidewalk curb ramps shall be in accordance with ASTM C 902, Class SX, Type II. The color shall approximate 30109 or 30166 in accordance with Federal Standard No. 595a. The color shall be consistent throughout the brick. The truncated domes shall be as shown on the plans. The minimum dimensions of the brick shall be 60 mm (2 1/4 in). thick by 90 mm (3 5/8 in.) wide by 195 mm (7 5/8 in.) long. The minimum thickness shall not be measured within the area of the domes.

SECTION 906 – JOINT MATERIALS

906.01 Joint Fillers. Joint fillers shall be preformed materials intended to be used in PCCP and bridge joints or as otherwise specified. Joint fillers shall be in accordance with AASHTO M 153. The asphalt content will be determined in accordance with ITM 801.

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 32°C (90°F). The sealant shall be placed when the ambient temperature is above 4°C (40°F). 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.

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.

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 5329 except that after blotting, the surface of the blocks shall be blown surface dry with compressed air.

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.

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 Materials and Tests Division for testing. The basis for 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 916.03(b). The lubricant-adhesive shall be covered by a type C certification in accordance with 916.03(d).

(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 315. 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. Joint sealing compound shall be in accordance with AASHTO M 198.

(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 -7°C (20°F) and 38°C (100°F).

(b) 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.

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

PROPERTY	TEST METHOD	REQUIREMENT
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.
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.

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.

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

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.

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 5973 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, and BS11. 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.)

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.

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:

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.

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

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.

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 placement of the steel reinforcement is in accordance with the 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.

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.

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.

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.

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.

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.

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.

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.

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;

(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

(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 _____ 20____.

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.

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.

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.

907.24.1 Thermoplastic Pipe Liners. Thermoplastic pipe liners shall be high density polyethylene or polyvinyl chloride pipe with sufficient rigidity to withstand the installation operation and shall exhibit a minimum amount of distortion. The liner shall be free from visible cracks, holes, foreign inclusions, or other defects. Thermoplastic pipe liners may be added to the Department's approved list by completing the requirements of ITM 806, Procedure A.

(a) Solid Wall HDPE Pipe Liner. Solid wall HDPE pipe liner shall be in accordance with ASTM F 714. The maximum standard dimension ratio, SDR, for the liner as defined in ASTM F 412 shall be 32.5. The resin used in the fabrication of the liner shall have a minimum cell classification of 345464C as shown in ASTM D 3350.

A 300 mm (12 in.) section of the liner shall show no evidence of splitting, cracking, or breaking when compressed between parallel plates to 40% of its outside diameter within 2 to 5 min.

(b) Profile Wall HDPE Pipe Liner. Profile wall HDPE pipe liner shall be in accordance with ASTM F 894. The minimum liner ring stiffness constant, RSC, shall be 100. The resin used in the fabrication of the liner shall have a minimum cell classification of 345434C as shown in ASTM D 3350.

(c) Profile Wall PVC Pipe Liner. Profile wall PVC pipe liner shall be in accordance with ASTM F 949, with the exception that PVC material with a minimum cell classification of 12454B as shown in ASTM D 1784 is added to the list of acceptable PVC materials.

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.

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.

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.

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:

(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.

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).

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.

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.

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.

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.

The asphalt material for coating shall be in accordance with 902.01(e). 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 204°C ± 3°C (400°F ± 5°F). 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

(b) When the pipe is preheated it shall be brought to a temperature of 149°C (300°F) and the asphalt shall be heated to a temperature of 193°C ± 3°C (380°F ± 5°F) 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.).

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 m^2 (131 sq ft) and 787 mm (31 in.) for openings over 12.2 m^2 (131 sq ft). The minimum radius of the arc shall be 787 mm (31 in.) for openings from 9.1 m^2 (98 sq ft) up to and including 19.8 m^2 (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 coatings, paints, 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.

Paints and coatings 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. Paints and coatings 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 or coating that are stored for future use may be re-sampled and retested.

Paints and coatings 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 or coating, 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 25°C (77°F). 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 25°C (77°F) and the stated number of liters (gallons) in the container.

All containers shall be labeled 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.

1. Multi-Component Inorganic Zinc Silicate Primer. These primers 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 primer shall be packaged in such proportions that when the full quantity of each component is mixed together, the specified mixed primer shall be yielded.

These inorganic primers shall be in accordance with AASHTO M 300.

2. Organic Zinc Primer. Organic zinc primer shall be a self-curing type primer. 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 84% metallic zinc. Table I, total zinc dust, percent by mass (weight) of total solids requirement shall be a minimum of 72% metallic zinc. The viscosity variation in Kreb Units in Section 6.2 shall be $\pm$ 10.

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 μm (6 mil) blade clearance to a tin coated steel panel at 25°C and 60% $\pm$ 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.

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.

3. Approval of Formulation. The manufacturer shall obtain approval of the formulation prior to furnishing the primers. Only zinc primers from the Department's list of approved Coating Formulations shall be used. Zinc primers will be placed and maintained on the Department's list of approved Coating Formulations in accordance with ITM 606.

(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%
Set-to-touch, ASTM D 1640, 150 μm (6 mils) wet film thickness, 25 $\pm$ 1°C, Max.	4 h
Potlife, 25 $\pm$ 1°C, Min.	6 h
Mass (weight)/volume variance from the initially approved batch, ASTM D 1475, 25°C, 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.

(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 (5 mils) wet film thickness, 25 $\pm$ 1°C, 50 $\pm$ 10% relative humidity, Min.	30 min
Total Solids ASTM D 2369, Min.	70%

Specular gloss, 60°, ASTM D 523, Min. 75
Viscosity, ASTM D 562, Kreb Units, Max. 100
Contrast ratio, ASTM D 2805, 127 ± 13 μm (5 ± 0.5 mils)
wet film thickness, dried 24 h @ 25 ± 2°C on Leneta Form 2A
or 2C, Min..... 0.95
Dry hard, ASTM D 1640, 127 μm (5 mils) wet film thickness,
25 ± 1°C, 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.

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.

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.

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

Viscosity, ASTM D 562, Kreb 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. 48
Vehicle solids, % of vehicle by mass (weight), Min. 37.5
Dry time, ASTM D 1640, 75 μm (3 mils) wet film thickness on a tin
coated steel panel @ 25 ± 1°C and 50 ± 5% relative humidity, Max:
Set-to-touch, h..... 1
Dry hard, h 24

Contrast ratio, ASTM D 2805, 125 ±13 μm (5 ± 0.5 mils) wet film thickness dried 24 h @ 25 ±2°C on Leneta Form 2A or 2C, Min. 0.97
Specular gloss, 60°, 250 ± 13 μm (10 mils ±0.5 mils) wet film thickness on a tin coated steel panel, dried 48 h @ 25°C and 50 ± 5% relative humidity, ASTM D 523, Max.....30
pH, ASTM E 70..... 7.0 - 9.0
Volatile organic compounds, ASTM D 3960, Max. ..... 0.180 kg/L (1.50 lb/gal.)

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.

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. Only waterborne finish paint from the Department's list of approved Coating Formulations shall be used. Waterborne finish paint formulations will be placed and maintained on the list of approved Coating Formulations in accordance with ITM 606.

(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, 60°, ASTM D 523, Max.....25.0
Mass (weight)/volume variance from the initially approved batch, ASTM D 1475, 25°C, Max..... 0.048 kg/L
Total solids variance from the initially approved batch, ASTM D 2369, Max. 2.0%
Volatile Organic Compounds, ASTM D 3960, Max. ..... 336 g/L

The dried paint film shall match color number 20045 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.

(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.

(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.

(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. Only structural steel coating systems from the Department's list of approved Structural Steel Coating Systems shall be used. Structural steel coating systems will be placed and maintained on the Department's list of approved Structural Steel Coating Systems in accordance with ITM 606.

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.

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) Blank.

(b) Fast Dry Traffic Paint.

1. General Requirements. The general requirements specified in 909.01 shall apply except as modified herein.

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.

The paint shall be ground to a uniform consistency, and it shall permit satisfactory application by the pressure spray type of painting machine. 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 μm (0.015 in.) on clean dry pavement, with the material being heated at a maintained temperature from ambient air temperature to a maximum of 82°C (180°F), at the atomized spray gun, at a minimum ambient temperature of 4°C (40°F). 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 4°C (40°F) through pumps from the shipping container into the paint tank on the paint machine, and then by pumps 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 μm (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 82°C (180°F) at the spray orifice. This maximum no tracking time shall not be exceeded when the pavement temperature varies from 2°C (35°F) to 49°C (120°F), 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 @ 25°C (77°F), ASTM D 562, Krebs Units	80	100
C.I.E. illuminant C, 2° standard observer, ASTM E 1349, percent		
White	84	---
Yellow	50	---
Color, yellow only, x-y C.I.E. coordinates for green limit, FHWA color chart of June 1965 C.I.E. illuminant C, 2° standard observer	Match the green limit ± 8%	
Contrast ratio, ASTM D 2805, wet film 380 ± 25 μm (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 65°C (150°F). 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 5°C (40°F). 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 μm (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 60°C (140°F) at the spray guns. The maximum no-tracking time shall not be exceeded when the pavement temperature varies from 10°C to 50°C (50°F to 120°F), 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.

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.

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	--
Pigment by mass, ASTM D 3723, %	45.0	57.0

Vehicle solids by mass of the vehicle, %	44.0	--
Viscosity, ASTM D 562, Kreb Units	75	95
Unit mass @ 25°C (77°F) ASTM D 1475, kg/L (lb/gal.)	1.498 (12.50)	--
Unit mass @ 25°C (77°F), variation between manufacturer's production batches, ASTM D 1475, g/L (lb/gal.)	--	24 (0.20)
Dry time, ASTM D 711, 380 μm (15 mils) wet film thickness, at 25°C (77°F), 50% $\pm$ 5% relative humidity, airflow of less than 1.4 m^3/min (50 ft^3/min), without glass beads,	--	10 min
Reflectance Factor, Y, C.I.E. illuminant, C, 2° standard observer, ASTM E 1349, 380 μm (15 mils) wet film thickness, air dried a minimum of 16 h, %		
White	84	--
Yellow	50	57
Color, yellow only, x & y C.I.E. Coordinates for the strong limits of FHWA color chart PR1, 380 μm (15 mils) wet film thickness, air dried a minimum of 16 h, measured on white background, C.I.E. illuminant, C, 2° standard observer, % deviation	Match the strong limits	$\pm$ 6.00
Coarse material retained on a 600 μm (No. 30) sieve, ASTM D 185, %	--	0.05
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 μm (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)

Abrasion resistance, Federal Specifications TT-P 1952B, L	190	--
Freeze-thaw stability, Federal Specification TT-P 1952B, change in consistency, Kreb Units	--	10
Heat stability, Federal Specifications TT-P 1952B, change in consistency, Kreb Units	--	10
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.	
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.

3. Formulation Approval. The manufacturer shall obtain approval of the waterborne traffic paint formulations prior to furnishing the paints. Only waterborne traffic paints from the Department's list of approved Coating Formulations shall be used. Waterborne traffic paint formulations will be placed and maintained on the Department's list of approved Coating Formulations in accordance with ITM 606.

909.06 Blank.

909.07 Blank.

909.08 Blank.

909.09 Epoxy Penetrating Sealers.

(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.

Non-volatile, or non-reactive extenders will 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).

(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. Non-volatile extenders will 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, 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 @ 25°C, (77°F) Poises	5-7	100-180	ASTM D 2196, Method A
Color (Gardner) Max.	5	5	ASTM D 1544
COMPONENT A			
Viscosity @ 25°C, (77°F) cps, Max.	40	40	ASTM D 2196, Method A
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 @ 25°C, (77°F) cps, Max.	40	40	ASTM D 2196, Method A
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 @ 25°C, (77°F) cps, Max.	40	40	ASTM D 2196, Method A
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 Permeability, %, 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 @ 21°C to 27°C (70°F to 80°F).
(Note 3) Applied to tin-coated steel panel, approximately 20 ga., previously warmed to 32°C ± 1°C (90°F ± 2°F).
(Note 4) Method 4061.1, applied at mixture temperature of 32°C ± 1°C (90°F ± 2°F).

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 @ 20/20°C	1.24-1.30	ASTM D 1963
Viscosity at 25°C, Poises	7-12	ASTM D 2196, Method A
pH, Water Extract	6.0-8.0	AASHTO T 200
Moisture Content, %	0.1 Max.	Fed Test Method Std. 141A Method 4082
Pour Point °C	-26.8 Max.	ASTM D 97
Molecular Mass Av.	1000 Max.	Empirical Formula
Flash Point, (Cleveland) °C	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 2°C (35°F) or above, and with an ambient air temperature of 2°C (35°F) or above. The material shall be in accordance with 909.09(c), except the set-to-touch shall be determined at -7° ± 1°C (20° ± 2°F) when applied to a tin coated steel panel at a mixture temperature of 25° ± 1°C (77° ± 2°F).

(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 obtain approval of formulation. Only epoxy penetrating sealers from the Department's list of approved Coating Formulations shall be used. Epoxy penetrating sealers will be placed and maintained on the Department's list of approved Coating Formulations in accordance with ITM 606.

909.10 Proprietary PCC Sealers. Proprietary PCC sealers shall be selected from the Department's Approved List of Other Concrete Sealers. A proprietary PCC sealer may be added to the approved list by completing the requirements in accordance with ITM 806, Approved List Procedure C.

(a) Properties. The proprietary PCC sealer shall be in accordance with NCHRP 244, Series IV, Southern Climate Weathering Test and possess the following properties.

Property	Requirement
Reduction of Chloride Ion Content	90% of the Control
Active Ingredients, Minimum	
Silane Based	20%
Siloxane Based	15%
Others	10%

(b) Test Report. Testing shall be performed by a recognized laboratory in accordance with ITM 806.

The proprietary PCC sealers shall be delivered to the jobsite in unopened containers with the manufacturer's numbered seal intact.

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 4°C (40°F); class B for use between 4°C (40°F) and 16°C (60°F); and class C for use above 15.5°C (60°F). Material furnished under this specification shall be covered by a type C certification in accordance with 916.

910.01 Reinforcing Bars and Dowel Bars.

(a) General. Unless otherwise specified, bars for concrete reinforcement shall be deformed billet steel, grade 420 (60). 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).

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.

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/in^2). An epoxy coating with a minimum film thickness of 150 μm (6 mils) shall be applied to the coupling device.

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.

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.

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.

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.

Low relaxation strand with a nominal diameter of 12.70 mm (1/2 in.) and a cross sectional area of 108 mm^2 (0.167 in^2) 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.

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 200 to 325 μm (8 to 13 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 @ 4°C (40°F)
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 -10°C (15°F) 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.

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.

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.

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.

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 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).

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.

(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.

(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.

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.

(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.

(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 mm^2 (1/2 sin.). Blowholes shall not be deep enough to affect the strength of the casting adversely.

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.

(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.

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.

910.08 Blank.

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

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/m^2 (3.60 oz/sq ft) minimum single spot and 1.22 kg/m^2

(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/m^2 (2.0 oz/ft^2) 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 Federal Specification TT-P-641, type II, or Military Specifications DOD-P-21035. When spray paints are used, two coats shall be applied.

910.10 Guardrail Posts. Guardrail posts shall be either steel 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 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) 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.

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.

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).

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.) $\pm$ 0.66 mm ($\pm$ 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.

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

7. For cable terminal anchor system, the anchor bracket, end plate, soil plate, bearing plate, strut and yoke shall be in accordance with AASHTO M 270M grade 250. They shall be zinc coated after fabrication in accordance with AASHTO M 111. The steel tube shall be in accordance with ASTM D 500 grade B and zinc coated in accordance with AASHTO M 111. The post sleeve shall be in accordance with ASTM A 53 grade B and zinc coated in accordance with AASHTO M 111. The stud shall be in accordance with ASTM F 568 class 8.8, and zinc coated in accordance with AASHTO M 111. The threads shall be in accordance with ANSI B1.13M and shall be M24 x 3 class 6g pitch. The swaged fitting shall be in accordance with ASTM A 576 grade 1035, zinc coated in accordance with AASHTO M 111, and shall be annealed for cold swaging. A lock pin hole to accommodate a 6 mm (1/4 in.) plated spring-steel pin shall be drilled through the head of the swaged fitting.

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.

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).

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.

The wire rope used in the cable assemblies shall be in accordance with AASHTO M 30 and shall be 19 mm (3/4 in.) preformed, 6 by 19, 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 lbf). 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 Steel Tube Guardrail.

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.

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.

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 Certification of Guardrail Suppliers. Suppliers desiring to be on certification status will be approved upon request and added to the Department's list of approved Certified Guardrail Suppliers. The written request shall be submitted to the Materials and Tests Division. An approval number will be assigned to each supplier to be used for identification acceptability of material.

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

The installer shall prepare and attach to each monthly material record a certification in accordance with 916.02(e). Such certification shall contain the contract number; supplier's name; supplier'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.

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 supplier.

Selected contracts with failing results will be adjudicated as a failed material in accordance with normal Department practice.

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

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.

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.

(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.

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/m^2 (0.75 oz/sq ft) average, and 214 g/m^2 (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/m^2 and 92 g/m^2 (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 3.8 mm (No. 9 gage). 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, Brinnel 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, except those used for temporary construction signs, temporary traffic signs, and temporary panel signs, 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 $\pm$ 25 mm ($\pm$ 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, except those used for temporary construction signs, temporary traffic signs, and temporary panel signs, 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, except those used for temporary construction signs, temporary traffic signs, and temporary panel signs, shall be covered by a type C certification in accordance with 916.

(e) Square Steel Posts. Square steel sign post, except those used for temporary construction signs, temporary traffic signs, and temporary panel signs, 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 ± 46 g/m^2 (0.60 ± 0.15 oz/ft^2) followed by a chromate conversion coating weighing 0.02 ± 0.006 g/m^2 (15 ± 5 micrograms μg/in.^{2}) and a clear organic exterior coating with a dry film thickness of 5 ± 2.5 μm (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 ± 15 μm (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 1/2 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.

910.15 Delineator Posts. Posts shall be in accordance with 910.14(a)1.

Physical requirements for the finished delineator posts shall be:

Width of flange face	50 to 60 mm (2 to 2 3/8 in.)
Width of back	19 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)	1.5 to 2.2 kg/m (1.0 to 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.

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.

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 $\pm$ 0.0125 mm (0.0005 in.). Curved bearing surfaces shall be machined to a tolerance of $\pm$ 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.

(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/m^2 (2.0 oz/sq ft) and no less than 549 g/sq m^2 (1.8 oz/sq ft) for any individual specimen. For aluminum coated fabric, coating shall be class II, 122 g/m^2 (0.40 oz/sq ft) minimum.

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.

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.

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 $\pm$ 4.5 $\pm$ 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/m^2 (0.80 oz/sq ft) for galvanized wire and 122 g/m^2 (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.

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.

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.

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/m^2 (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.

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/m^2 (0.75 oz/sq ft) for line wires and 214.0 g/m^2 (0.70 oz/sq ft) for barbs.

(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	Swing Gate Opening, (inclusive)	
Size	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)

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.

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).

(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.

b. Suppliers not qualified or not desiring to furnish pretested approved stockpiled material.

2. Suppliers of Pretested Approved Stockpiled Material. Suppliers desiring to furnish pretested approved stockpiled material shall contact the District Materials and Tests Engineer. A written request will not be required.

The requirements set out in the General Procedures for Controlling Materials Approved Prior to Delivery to the Project will apply with the following additions, modifications, or clarifications.

a. Posts, braces, or similar pieces shall be bundled before or after sampling, but prior to approval.

b. All tests will be performed at the Materials and Tests Division.

c. Basis of acceptance will be a car seal attached to each roll of fence, barbed wire or tension wire, and each bundle of posts. Acceptance numbers will not be issued for accessories such as posts caps, brackets or tie wires.

d. If a complete roll or bundle is not shipped, the car seal shall be retained with the unused portion. The number shall be supplied to the Engineer for the material acceptance.

3. Suppliers Not Furnishing Pretested Approved Stockpiling Material. Suppliers not desiring to retain status or who lose status to furnish pretested stockpiled material will have their material inspected at the project site after delivery. No material may be used until it has been tested and approved.

910.19 Overhead Sign Structures. The complete structure with signs in place shall be able to withstand wind pressure in accordance with AASHTO specifications for the Design and Construction of Structural Supports for Highway Signs. The structure shall be designed to resist movement by the wind which might contribute to the fatigue of the material.

All prefabricated structural units shall be packed so that there is no injury or defacement during transportation to the point of destination.

All bolts, nuts, and washers for bridge bracket assemblies shall be stainless steel in accordance with ASTM F 738M.

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.

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.

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.

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.

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.

(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.

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.

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.)
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.

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/m^2 (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 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.

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.

(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.

(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.

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.

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).

910.22 Welding Supplies.

(a) Aluminum Alloy Base Metals.

1. Bare Wire Electrodes and Welding Rods. Bare wire electrodes for use with the gas metal arc welding process and welding rods for use with the gas tungsten-arc welding process shall be in accordance with the Specifications for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes, ASTM B 285 or AWS A5.10. Tungsten electrodes for the gas tungsten-arc welding process shall be in accordance with the Specifications for Tungsten-Arc Welding Electrodes, ASTM B 297 or AWS A5.12.

2. Filler Metal. Filler metals to be used with particular base metals shall be as shown in the table below. Other filler metals may be used if approved.

Base Metal	Filler Metal
3003 to 3003	ER1100
3004 to 3004	ER4043
5052 to 5052	ER5356*
5083 to 5083	ER5183
5086 to 5086	ER5356*
5456 to 5456	ER5556
6061 to 6061	ER5356*
6063 to 6063	ER5356*
356.0 to 6061	ER4043
356.0 to 6063	ER4043

*ER5183, ER5356, and ER5556 may be used interchangeably for these base metals.

Filler metals shall be kept covered and stored in a dry place at relatively uniform temperatures. Original rod and wire containers shall not be opened until time to be used. Rod and wire shall be free of moisture, lubricant, or other contaminants. Spools of wire temporarily left unused on the welding machine shall be kept covered to avoid contamination by dirt and grease collecting on the wire. If a spool of wire is to be unused for more than a short length of time, it shall be returned to the carton and the carton tightly sealed.

3. Shielding Gases. Shielding gases shall be welding grade or better. Shielding gas for gas metal-arc welding shall be argon, helium, or an approximate 75% helium and 25% argon mixture. Shielding gas for gas tungsten-arc welding done with alternating current shall be argon. Shielding gas for gas tungsten-arc welding done with direct current, straight-polarity, shall be helium.

Hose used for shielding gases shall be made of synthetic rubber or plastic. Hose which has been previously used for acetylene or other gases shall not be used.

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.

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.

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.

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.

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.

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.

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

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.

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.

(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 200 (8)	3 (1/8)	6 (1/4)	6 (1/4)	10 (3/8)
	200 (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)
	200 (8) and over	6 (1/4)	10 (3/8)	10 (3/8)	13 (1/2)
Over 50 (2) but	under 200 (8)	6 (1/4)	6 (1/4)	10 (3/8)	10 (3/8)
Less than 200 (8)	200 (8) and over	6 (1/4)	10 (3/8)	10 (3/8)	13 (1/2)
200 (8) and over	200 (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 mm^2 (16 sin.) 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.

	Diameter - mm (Inches)		
Length of Pile	Tip Minimum	0.9 m (3') from Butt, Minimum	Butt Maximum
Less than 6.1 mm (20 ft)	200 (8)	279 (11)	508 (20)
6.1 m (20 ft) and less than 12.2 m (40 ft)	200 (8)	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 AWPA Standards. AWPA Standard C1 specifies general requirements for all wood products. Other AWPA 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).

(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 AWPA Standards.

(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 AWPA Standards.

(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.

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 AWPA Standards.

(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.

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 AWPA Standards. The oil carrier shall be a heavy petroleum solvent in accordance with the applicable provisions of Standard P9 of the AWPA Standards and shall be of such characteristics that the posts will be suitable for painting with an oil base paint.

(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	No. 1 or better	WWPA or WCLIB
Southern Pine	No. 1 or better	SPIB
Jack Pine 200 mm x 200 mm (8 in. x 8 in.)	No. 1 or better	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 AWPA and ASTM standards, AWPA will prevail. Where there is a conflict between either AWPA 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[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	No. 2 or better	WWPA or WCLIB
Southern Pine Species	No. 2 or better	SPIB
Jack Pine, Red Pine, and Eastern White Pine (Northern White Pine)	No. 1 or better.	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:

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.

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.

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.

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 911.02(f)2b.

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.

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.

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.

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.

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 AWPA 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 AWPA standards listed in Table C.

TABLE C

MATERIAL	AWPA Standard
Ammoniacal Copper Arsenate (ACA)	P5
Ammoniacal Copper Zinc 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 AWPA 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

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 49°C (120°F), 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.

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 °C (°F)	Max. Duration Hrs	Max.Temp °C (°F)	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.

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/m^3 (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 AWPA 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 AWPA 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 AWPA 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 Degrade After Treatment. Guardrail posts or blocks developing the following degrade prior to installation will be rejected regardless of prior approvals.

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.

(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 AWPA-P5, and shall be Acid Copper Chromate, Ammoniacal Copper Arsenate, or Chronmated Copper Arsenate.

SECTION 912 – CONCRETE CURING MATERIALS AND ADMIXTURES

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

(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 for use in PCC shall be selected from the Department's Approved List of Admixtures for PCC. An admixture may be added to the approved list by completing the requirements in ITM 806, Procedure D. Admixtures containing chloride added as an ingredient of manufacture are unacceptable.

(a) Air Entraining Admixtures. Air entraining admixtures are materials to be added to PCC mixtures at the mixer for the purpose of entraining air.

(b) Chemical Admixtures for Concrete. Chemical admixtures are materials to be added to PCC 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 an 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) Test Report. Testing shall be performed by a recognized laboratory in accordance with ITM 806 for their respective types.

1. Air entraining admixtures shall be in accordance with AASHTO M 154.

2. Chemical admixtures shall be in accordance with AASHTO M 194 for their respective types except that the test report for HRWR and HRWRR admixture systems shall be in accordance with the following additional requirements:

   a. The HRWR or HRWRR admixture system shall be used in the test concrete.

   b. The six month and one year compressive strength testing will be waived and flexural strength testing will not be required.

   c. Uniformity and equivalence testing will not be required.

   d. Testing for length change will not be required.

   e. 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 mm^2/mm^3 (500 $in.^2/in.^3$).

3. 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.

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:

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
FreezeCThaw Stability	Five Cycles, -15° to 25°C
Shelf Life	Two Years, Minimum
Color	White

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:

(a) pH	6 to 8.
(b) Chloride Ions	less than 300 ppm.
(c) Sulphate (SO_4)	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.

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.

913.07 Flexible Delineator Posts. Flexible delineator posts shall be made of high density polyethylene plastic in accordance with ASTM D 5203. The post shall be straight along its center line and have a smooth surface free from cracks, flaws, seams, laps, blisters, and edges affecting the strength, durability, or appearance. The cross section width shall not exceed 150 mm (6 in.).

The reflective sheeting on the post shall be in accordance with 913.10(b) and shall have minimum dimensions of 75 mm (3 in.) by 200 mm (8 in.). Reflective sheeting shall be applied directly to the post and protected in a manner that minimizes damage to the sheeting upon impact.

The color of the post and the reflective sheeting shall match the color of the adjacent edgeline.

When installed, the flexible post shall withstand, without damage, five vehicle impacts at ambient air temperatures of 0°C (32°F) and at 30°C (85°F) each. The vehicle impacts shall include both bumper and tire impacts 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.

Only flexible delineator posts from the Department's list of approved Flexible Delineator Posts shall be used. Flexible delineator posts will be placed and maintined on the Department's approved list in accordance with ITM 806, procedure G.

913.07.1 Tubular Marker. The vertically placed portion of this 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 or high impact polystyrene in accordance with ASTM D 4549. Epoxy material used to attach the base to the roadway surface shall be in accordance with the manufacturer's recommendations. The tubular portion shall be covered with high intensity reflective sheeting in accordance with 913.10(b).

913.08 Delineators.

(a) Acrylic Plastic Delineators. Acrylic plastic delineators 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 mm^2 (7 $in.^2$). The trademark of the manufacturer shall be molded legibly into the face of the lens. Color shall be clear, red, 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 Candelas/lux (candle power/footcandle)		
		Clear	Yellow	Red
0.1	0	11.1 (119)	7.3 (79)	2.6 (28)
0.1	20	4.4 (47)	2.6 (28)	1.0 (11)

Note: The observation angle is the angle at reflector between the observer's line of sight and direction of light incident on reflector. The entrance angle is the angle at the reflector between the direction of light incident on it and the direction of reflector axis. 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.

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. A single aluminum grommeted hole in the center of the reflector shall be provided for mounting. The inside diameter of the grommet hole shall be 5 mm (3/16 in.).

Only acrylic plastic delineator models and colors from the Department's list of approved Delineators shall be used. Acrylic plastic delineators will be placed and maintained on the Department's approved list in accordance with ITM 806, procedure G.

(b) Reflective Sheeting Delineators. Reflective sheeting delineators shall consist of reflective sheeting affixed to an aluminum backing material. The white delineator shall be 75 mm by 200 mm (3 in. by 8 in.) $\pm$ 3 mm ($\pm$ 1/8 in.). The yellow delineator shall be 125 mm by 125 mm (5 in. by 5 in.) $\pm$ 3 mm ($\pm$ 1/8 in.). The backing material shall be in accordance with 913.10(a) except the minimum thickness shall be 1.6 mm (0.064 in.). Reflective sheeting shall be in accordance with 913.10(b).

There shall be two mounting holes, 5 mm (3/16 in.) in diameter, with one at the top and one at the bottom. The holes shall be 150 mm (6 in.) $\pm$ 2 mm (1/16 in.) center to center for the rectangular shape. Holes shall be 125 mm (5 in.) $\pm$ 2 mm (1/16 in.) center to center and in the corners of the square units. Completed delineators shall be dip coated with a high gloss clear finish coat as specified and supplied by the sheeting manufacturer. The finished units shall be clean cut, sharp, and have essentially a plane surface.

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.

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 mm^2 (6.5 $in.^2$), shall be methyl methacrylate in accordance with Federal Specification LP-380C, type 1, Class 3. Photometric or optical requirements shall equal or exceed the minimum values in 913.08(a).

Only barrier delineator models and colors from the Department's list of approved Delineators shall be used. Barrier delineators will be placed and maintained on the Department's approved list in accordance with ITM 806, procedure G.

(d) Temporary Barrier Delineator. Temporary barrier delineators shall consist of a type III sheeting in accordance with 913.10(b)1 affixed to a reboundable substrate. The delineator shall be 200 by 300 mm (8 by 12 in.) vertically mounted. The mounting bracket used to affix the delineator to the barrier shall not be more than 75 mm (3 in.) vertical.

913.09 Glass Beads. Glass beads shall be in accordance with AASHTO M 247, Type I except sampling shall be in accordance with the frequency manual. The beads shall have a moisture resistant coating.

913.10 Traffic Signs. Traffic signs shall be in accordance with the MUTCD.

Panel sign fabrication shall not utilize overlapping or butt splicing of reflective sheeting. Roll splices, as supplied on the roll of sheeting by the sheeting manufacturer, are permitted subject to the following conditions:

(a) a maximum of one roll splice per panel, and

(b) a maximum of three roll splices per sign.

Exit panels are considered a part of the signs to which they are attached when fabricated under the same contract. If the exit panels are made for separate installation, only one roll splice is permitted on the entire sign.

Overlap splices on sheet signs will 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 splices shall not be used. Roll splices are permitted on sheet signs but shall not exceed one splice per sign.

All signs shall be packed for shipment and handled during construction in accordance with the manufacturer's recommendations. All sign or sign face damaged prior to acceptance shall be replaced or repaired. Damaged sheet signs shall be replaced in their entirety. Damaged panel signs shall have the affected panels replaced or repaired 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 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 larger than 25 mm by 25 mm (1 in. by 1 in.) shall be limited to one per panel and a maximum of three per panel sign. The maximum number of repaired areas shall be three on a panel or six on a panel sign. No more than 20% of the total number of panel signs may be patched. Panels with sheeting cracked at the bend around the panel edge shall be replaced.

A sign with the metal face damaged greater than superficial deformation shall be replaced.

(a) Backing Material. 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 a plane surface.

Metal sign base material shall be cleaned and prepared to receive the sheeting material in accordance with the sheeting manufacturer's recommendation.

1. Sheet Signs. The backing material for permanent sheet signs shall be sheet aluminum in accordance with ASTM B 209M (ASTM B 209), alloy 5052H38, or alloy 6061-T6.

The minimum thickness of the sheet shall be as shown for the appropriate sign width.

Width, mm (in.)	Thickness, mm (in.)
Up to 750 (30)	2.00 (0.080)
775 to 1500 (31 to 60)	2.50 (0.100)
1525 and over (61 and over)	3.20 (0.125)

Backing material for temporary ground mounted signs shall be aluminum, steel, fiberglass, reinforced plastic, or plywood, unless otherwise approved.

2. Panel Signs. Extruded aluminum panels shall be in accordance with ASTM B 221M (ASTM B 221), alloy 6063-T6, and be 300 mm (12 in.) in width. Extruded aluminum panels shall be flat and straight within tolerances established by the aluminum industry. The mass (weight) for panels shall be 3.70 kg/m (2.48 lb/ft).

Trim molding shall be of the same material and thickness as the panels to which it is attached.

Panel bolts, flat washers, and lock-nuts shall be in accordance with ASTM B 211M (ASTM B 211), alloy 2024-T4. Panel bolts shall be 10 by 19 mm (3/8 by 3/4 in.) standard hex head. Lock-nuts shall be standard hex head.

3. Demountable Letters, Numbers, and Symbols. Backing material for letters, numerals, and symbols shall be 1.0 mm (0.040 in.) thick aluminum sheets in accordance with ASTM B 209M (ASTM B 209), alloy 3003-H14. Borders shall be 0.8 mm (0.032 in.) thick aluminum sheet in accordance with ASTM B 209M (ASTM B 209), alloy 6061-T6.

(b) Sheeting Material. Only sheeting materials from the Department's list of approved Sign Sheeting Materials shall be used. Sheeting materials will be placed and maintained on the Department's approved list in accordance with ITM 806, procedure G.

1. Reflective Sheeting. Reflective sheeting used for signs and channelizing devices. shall be in accordance with AASHTO M 268. Type I, II, III, or IV reflective sheeting shall be used on signs, delineators, and barricades. Type V reflective sheeting may be used on delineators. Type VI reflective sheeting shall be used for temporary roll up signs, traffic cone collars, and post bands. Type III, Class I, reboundable reflective sheeting shall be used on plastic drums, flexible delineator posts, and other flexible channelizers.

The reflective sheeting shall include an adhesive backing Class 1 or Class 2 in accordance with AASHTO M 268.

2. Nonreflective Sheeting. Nonreflective sheeting shall be in accordance with AASHTO M 268 except that the sheeting shall not incorporate optical elements. The color shall be black in accordance with Federal Standard 595 a, Color No. 17038.

3. Transparent Sheeting. Transparent sheeting shall be of a material recommended by the background sheeting manufacturer.

(c) Letters, Numerals, Symbols, and Accessories. Letters, numbers, symbols, and accessories shall be demountable.

The reflective sheeting shall be of the same type as used on the background and mechanically applied to the properly prepared aluminum in a manner prescribed by the sheeting manufacturer.

Each demountable legend unit, supplemental panel, and border frame shall be supplied with mounting holes and shall be secured to the sign face with aluminum rivets with aluminum mandrels. Adhesives that, when removed, may damage the sign face, legend unit, or border shall not be used to hold the unit in place.

Completed demountable units shall be dip coated with a high gloss clear finish coat as specified and supplied by the sheeting manufacturer. The finished units shall be clean cut, sharp, and have essentially a plane surface.

(d) Fasteners.

1. Sheet Signs. The bolts, steel flat washers, and lock-nuts used to attach sheet signs to posts shall be stainless steel in accordance with ASTM A 276, or type 304 carbon steel in accordance with ASTM A 307, grade A. Carbon steel hardware shall be galvanized in accordance with ASTM A 153. Lock washers and hex nuts shall be used in lieu of the lock-nuts when carbon steel hardware is furnished.

The bolts shall be 8 mm by 75 mm (5/16 in. by 3 in.)hex head, full threaded. The steel flat washers shall be size no. 1/4, 19 mm (0.738 in.) outside diameter, 8.1 mm (0.317 in) inside diameter, and 1.2 to 2.0 mm (0.051 to 0.08 in.) thick and in accordance with Military Specifications MS 15795-811. Nylon flat washers shall be 22 mm (7/8 in.) outside diameter, 8.1 mm (0.317 in.) inside diameter, and shall be 0.81 mm (0.032 in.) thick.

2. Panel Signs and Temporary Panel Signs. The aluminum post clips shall be in accordance with ASTM B 26M (ASTM B 26) or ASTM B 108M (ASTM B 108), alloy 356.0-T6 and as shown on the plans. Aluminum post clip bolts shall be as shown on the plans and in accordance with ASTM B 211M (ASTM B 211), alloy 2024-T4. Lock-nuts shall be in accordance with ASTM B 211M (ASTM B 211), alloy 2017-T4. Flat washers shall be in accordance with ASTM B 209M (ASTM B 209), alloy Alclad 2024-T4.

3. Aluminum Rivets. Aluminum rivets shall be determined by character size and shape but shall not be more than 20 mm (8 in.) on center. All rivets shall be color matched to the legend or supplemental panel being installed.

(e) Basis for Use. Materials furnished under this specification, except those used for temporary construction signs, temporary traffic signs, and temporary panel signs, shall be covered by a type C 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.

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.

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.

Conventional light standards shall be designed to support a 24 kg (53 lb) luminaire with an effective projected area of 0.22 m^2 (2.4 ft^2). 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.

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.

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.

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)

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)

The effective mounting heights for other nominal mounting heights deviate from the table by the difference in the nominal heights.

2. Aluminum Lighting Standards.

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.

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.

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.

4. Galvanized Steel Lighting Standards. The pole and base plate shall be fabricated from steel in accordance with ASTM A 572M (ASTM A 572), A 595, or A 1011 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.

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.

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.

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.

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.

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 $\pm$ 0.28 mm (0.918 in. $\pm$ 0.011 in.) and out-of-round tolerance shall be $\pm$ 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.

(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 m^2 (2.8 ft^2) 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.

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).

All steel used in the base plate and shaft shall meet an impact property of 20.3 J (15 ft·lbs) at + 4.5°C (+ 40°F) 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 ft·lbs). 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.

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.

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.

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.

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 mm^2 (4 $in.^2$). 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.

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 m^2 (2.8 ft^2) 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.

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.

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.

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.

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.

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).

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.

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 ft·lbs.) 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 mm^2 (8 $in.^2$), 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.).

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.

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.

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.)

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 75°C in wet locations.

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.

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.

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 90°C; THHN 90°C; THWN 75°C; and AWM 105°C. 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.

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.

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.

(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 -7°C (20°F) with an input voltage variation of ±10% of the rated operating voltage specified.

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.).

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, 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.

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.

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 borsillicate 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.

(e) Circuit Breakers and Enclosure. All circuit breaker enclosures shall be NEMA 4/5.

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 fastner 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.

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:

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 -40°C (-40°F) to 85°C (185°F);

d. lug range 1/0 - 14 copper and 1/0 - 12 aluminum; and

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.

(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.

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.

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;

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

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.

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 -29°C (-20°F) to + 66°C (150°F).

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.

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.

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).

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.

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).

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.

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-controlled 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 photo-controlled 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).

(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.

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 20° horizontal and 6° 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.

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.

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 801.15(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.

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.

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 in accordance with AASHTO M 249.

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 HMA or PCCP 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.

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.

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.

(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 21°C (70°F) and 27°C (80°C) 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).

(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 21°C (70°F) and 27°C (80°F).

(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 mm^2 (1 $in.^2$) 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 21°C (70°F) and 27°C (80°F) and at a speed of 50 mm (2 in.) per minute.

(4) Bend Test. At a temperature of 27°C (80°F) 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.

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 except materials used for temporary pavement markings.

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.

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.

(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 μm ± 38 μm (15 mils ± 1 1/2 mils) to code S-16 stainless steel plates. The films shall be allowed to cure at a temperature between 21°C (70°F) to 27°C (70°C) for 72 h prior to performing the indicated test. The test panel shall be unbeaded.

(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 μm ± 38 μm (15 mils ± 1 1/2 mils) in thickness and allowed to cure at a temperature between 21°C (70°F) to 27°C (80°F) 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 21°C (70°F) to 27°C (80°F) for 72 h prior to performing the indicated tests. The rate of pull shall be 6.4 mm (1/4 in.) per minute.

(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 21°C (70°F) to 27°C (80°F) 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.

(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 μm $\pm$ 25 μm (15 mils $\pm$ 1 mils) with no glass beads and cured at a temperature between 21°C (70°F) to 27°C (80°F) 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 50°C (122°F) 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.

(7) Laboratory Drying Time. The epoxy pavement marking material shall be mixed in the proper ratio and applied at 375 μm $\pm$ 38 μm (15 mils $\pm$ 1 1/2 mils) wet film thickness at 24°C $\pm$ 1°C (75°F $\pm$ 2°F) 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.

b. Materials Preparation. Before mixing, the individual components shall be heated to the following temperatures:

Component	Temperature °C (°F)
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 32°C (90°F) and 38°C (100°F).

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 1.7°C (35°F) and 38°C (100°F).

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 and material used for temporary pavement markings, 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 38°C (100°F) 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 selected from the Department's list of approved Temporary Pavement Marking Tape, Type I. Temporary pavement marking tape type I will be placed and maintained on the Department's approved list in accordance with ITM 806.

Type I 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/m^2/lux (candlepower/ft^2/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	
	0.2°	0.5°	0.2°	0.5°
Specific Luminance, Type 1	1770	1270	1310	820
Specific Luminance, Type 2	1000	760	820	510

(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.

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 mm^2 (1.62 in^2). 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.

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.

(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.

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
0°	0.279 cd/lx (3.0 Candlepower/footcandle)
20°	0.1115 cd/lx (1.2 Candlepower/footcandle)

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.

(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.

(3) Heat Resistance Test. Three reflectors shall be tested for 4 h in a circulating air oven at 80° ± 3°C (175° ± 5°F). 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 55°C (130°F) 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 60°C (140°F) for 4 h followed by -7°C (20°F) 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 21°C (70°F). 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.

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.

(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.).

(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 -1°C (30°F) and 32°C (90°F) 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.

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.

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.

(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.

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 mm^2 (144 in^2). A minimum of 61900 mm^2 (96 in^2) 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 21°C (70°F) 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	265°C (509°F)
Bitumen content per ASTM D 2172	25-30%
Filler content (by subtraction)	70-75%
Filler particle size	Over 85% passing 200 mesh sieve (75 μm)
Penetration at 25°C (77°F) per ASTM D 5	12 $\pm$ 4
Softening point (Ring & Ball) per ASTM D 36	105°C $\pm$ 3°C (221°F $\pm$ 5°F)
Recommended pouring temperature	204°C - 218°C (400 - 425°F)
Shelf life	2 years
Packing	Silicone lined cardboard boxes containing approximately 28.1 kg (62 lbs) each

Note: Material shall not contain rubber polymers.

d. Acceptance Evaluation. Markers shall be selected from the Department's list of approved Temporary Raised Pavement Markers. Temporary raised pavement markers will be placed and maintained on the approved list in accordance with ITM 806.

913.15 Traffic Signal Materials and Equipment.

(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)6f(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)6f(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.

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:

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.

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.

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.

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.

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 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.

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 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 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.

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.

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.

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 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.

Pedestrian timing shall be provided on all phases of a controller.

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.

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.

(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.

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.

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.

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.

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.

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.

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 21° to 38°C (70° to 100°F). 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 m^3 (100 ft^3) 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 -34°C to 74°C (-30°F to +165°F). 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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%).

The base shall be designed to support a 68 kg (150 lb) axial load and 1.0 m^2 (11 ft^2) 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.

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 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.

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.

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.

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.

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.

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 $\pm$ 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.

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.

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.

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.

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.

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.

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.

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.

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.

The flasher shall operate between 95 volts and 135 volts AC 60 Hertz. No degradation of performance shall be experienced in environmental changes from -29°C to 74°C (-20°F to 165°F) 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.

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.

It shall have a screened vent in the bottom with a minimum size of 1129 mm^2 (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 21° and 43°C (70° and 110°F).

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.

(b) Interconnection Equipment.

1. Hardwire Interconnection.

a. Electro-Mechanical Dial Coordination Unit.

(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.

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.

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.

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.

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 varisters 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.

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 105°C (221°F). 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.

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.).

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.

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.

(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.

(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.

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.

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.

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).

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 mm^2 (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.

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.

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.

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.

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.

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.

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.

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.

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.

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.).

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 -35°C to 49°C (-35°F to 49°F) without failure.

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.

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

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.

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.

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.

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.

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.

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
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:

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.

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.

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.

(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.

The pole material shall be in accordance with ASTM A 595 or A 572 with a minimum yield strength of 345 MPa (50,000 psi). The pole shall be galvanized after fabrication in accordance with ASTM A 123.

All hardware, handhole cover and latching device, band type steel pole bands, 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/m^2 (2 oz/ft^2).

The pole bands 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 MPa (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.

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.

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.).

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 MPa (55,000 psi) or ASTM A 36M (ASTM A 36), special quality, modified to 379 MPa (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 mm^2 (4 1/2 $in.^2$) and 32 mm (1 1/4 in.) thick may be welded to the embedded end of the anchor bolt.

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 AWPA Standards C1 and C4, using preservative as outlined in standard P5 and set forth in 911.02(g).

Treatment, handling, and storage methods shall be in accordance with the current AWPA Standards.

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.

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.

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, whichever 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.

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 m^2 (2.4 ft^2). 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.

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.

(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.

(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.

(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 MPa (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/m^2 (2 oz/ft^2).

All hardware for aluminum poles shall be stainless steel in accordance with ASTM A 276, type 304 or type 305.

(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.

(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.

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.

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.

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 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 916.

i. Shop Drawings. Five sets of shop drawings and a set of design calculations shall be submitted to the Design Division for approval. A copy of the transmittal letter shall be sent to the Engineer. The approved drawings will be distributed by the Design Division.

4. Downguys, Anchors, Rods, and Guards. Pole anchors shall be 8 way expanding with a minimum area of 87,100 mm^2 (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.

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.

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).

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.

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.

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 μm 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 51-7 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).

(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.

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.

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.

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.

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.

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.

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 μm) 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.

** 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.

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.

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 selvedges. 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]
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)
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

[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.

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.

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.

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 selvedges. 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
Grab Strength	ASTM D 4632	41 kg (90 lb)	41 kg (90 lb)
Elongation at 20 kg (45 lb)	ASTM D 4632		50% Max.
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

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.

913.21 Geogrid. Geogrid shall be on a regular network of integrally connected polymer tensile elements with aperture geometry sufficient to permit significant mechanical interlock with the surrounding material. The geogrid structure shall be dimensionally stable and shall be able to retain its geometry under construction stresses. The geogrid structure shall have resistance to damage during construction, ultraviolet degradation, and all forms of chemical and biological degradation encountered in the soil being placed on.

Geogrid shall be in accordance with the property requirements as specified in the Geosynthetic Research Institute Standard Test Methods GG1, GG3, GG4, and ASTM D 5262.

During periods of shipment and storage, the geogrid shall be protected from temperatures greater than 60°C (140°F), mud, dirt, dust, and debris. Each geogrid roll shall be labeled or tagged to provide product identification. 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.

Only geogrids selected from the Department's list of approved Geogrids shall be used. Geogrids will be placed and maintained on the Department's list in accordance with ITM 806, procedure P. 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.

The geogrid shall be in accordance with the property requirements for the type specified as follows:

(a) Type I.

PROPERTY	TEST METHOD	UNIT	VALUE, Min.
Aperture	Calibered	mm (in.)	13 x 13 (0.5 x 0.5)
Open Area	COE, CWO2215	percent	>50.0, ≤ 80.0
Tensile Modulus,			
machine direction	GRI, GG1[1, 3,4]	N/m (lb/ft)	146,000 (10,000)
cross machine direction	GRI, GG1[1, 3,4]	N/m (lb/ft)	146,000 (10,000)

Ultimate Strength, machine direction	GRI, GG1[2, 3, 4]	N/m (lb/ft)	11,670 (800)
cross machine direction	GRI, GG1[2, 3, 4]	N/m (lb/ft)	11,670 (800)

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. Results for machine direction, MD, and cross machine direction, CMD, are required.

4. Minimum average roll values shall be in accordance with ASTM D 4759.

(b) Type II.

PROPERTY	TEST METHOD	UNIT	VALUE, Min.
Open Area	COE, CWO2215	percent	$>50.0, \leq 80.0$
Tensile Modulus, machine direction	GRI, GG1[1, 4]	N/m (lb/ft)	720,000 (49,300)
Creep Limited Strength, machine direction at 5% strain	GRI, GG3[2, 3]-87 or ASTM D 5262	N/m (lb/ft)	16,000 (1090)

1. Secant modulus at 2% elongation measured by Geosynthetic Research Institute Test Method GG1, Geogrid Tensile Strength. No offset allowance shall be made in calculating secant modulus.

2. Long term load capacity measured by through the junction tensile creep testing to 10,000 hours in accordance with Geosynthetic Research Institute Test Method GG3, Creep Behavior and Long Term.

3. The Long Term allowable design strength, LTADS, is determined in accordance with GR1-GG4, Determination of the Long Term Design Strength of Stiff Geogrids.

4. Minimum average roll values shall be in accordance with ASTM D 4759.

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 Temporary Seed. Temporary seed will be approved for use by visual inspection of the Engineer. Temporary seed may be purchased from any commercial source provided the seed's package is clearly marked and labeled by the manufacturer as to its content and weight.

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.

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.

Clover shall be free from dodder with no tolerance allowed. Lespedza 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.

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 Materials and Tests Division. 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.

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.

$$W \times P \times G = M \text{ or less}$$

$$P = \frac{\text{Minimum Specified Purity}}{\text{Actual Purity}}$$

$$G = \frac{\text{Minimum Specified Germination}}{\text{Actual Germination}}$$

W = Actual percent of weed seeds
P = Purity Factor
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.

Amount to be used = Amount specified x P x 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 Fescue	Festuca elatior (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 perfenne	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 Fescue	Festuca elatior (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 perfenne	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 officnalis	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 Fescue	Festuca elatior (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 perfenne	90
Kentucky Bluegrass	Poa prateusis	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.

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/m^2 (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/m^2 (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 $\pm$ 3 mm (1/2 in. $\pm$ 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/m^2 (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 μm (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.).

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.

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.

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.

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.

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.

(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.

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.

(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.

(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 2°C (35°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.

(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.

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

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.

(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 $\pm$ 2.2 g per m^2 (2.8 $\pm$ 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.

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.

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.

(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.

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:

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 spectorscopy 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.

(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%.

(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 23°C (73°F). 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.

(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.

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 μm (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 μm (8.0 mils) for individual measurements and 300 μm (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.

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.

(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
@ 70°C	Change in ultimate elongation,			
(158°F)	max. %	-25	-25	-25
	Compression Set			
D 395 Method B	22 h @ 70°C (158 °F), max. %	25	25	25
	Ozone			
D 1149	25 ppm ozone in air by volume, 20% strain 38°C ± 1°C (100°F ± 2°F), 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 @ -29°C ± 1°C (-20°F ± 2°F), 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
@ (100°C)	Change in ultimate elongation,			
212°F	max. %	- 40	-40	-40
	Compression Set			
D 395 Method B	22 h @ 100°C (212°F), max. %	35	35	35
	Ozone			
D 1149	100 ppm ozone in air by volume, 20% strain 38°C ± 1°C (100°F ± 2°F), 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 @ -29°C ± 1°C (-20°F ± 2°F), 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.

(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.)
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.)
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.)

(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 -29°C (-20°F). 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 Materials and Tests Division. 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.

(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.

(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.

(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.

(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

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

(b) Sample Type A Certification Form.

INDIANA DEPARTMENT OF TRANSPORTATION

TYPE A CERTIFICATE OF COMPLIANCE

CONTRACT NUMBER_____

PROJECT NUMBER_____

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:

**MATERIAL NAME	QUANTITY
_____	_____
_____	_____

***Conform to:_____

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
_____	_____	_____
_____	_____	_____
_____	_____	_____

_____ _____
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.

(c) Sample Type B Certification Form.

INDIANA DEPARTMENT OF TRANSPORTATION

TYPE B CERTIFICATE OF COMPLIANCE

CONTRACT NUMBER_____

PROJECT NUMBER _____

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:

**MATERIAL NAME	QUANTITY
_____	_____
_____	_____

***Conform to:_____

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
_____	_____
_____	_____

_____ _____

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.

(d) Sample Type C Certification Form.

CONTRACT NUMBER_____

PROJECT NUMBER _____

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:

**MATERIAL NAME QUANTITY

_____ _____

_____ _____

***Conform to:_____

_____ _____
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.

(e) Sample Type D Certification Form.

CONTRACT NUMBER _____

PROJECT NUMBER _____

MANUFACTURER'S NAME _____

MATERIAL DESTINATION _____

This is to certify that for the contract described above, the materials supplied are as follows:

**MATERIAL NAME	QUANTITY
_____	_____
_____	_____

*** Is in accordance with: _____

_____ _____
Date Contractor

* _____
Signature of Contractor Official/Title

* 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 letter. The Engineer will be responsible for the distribution of the letter.

ASBESTOS EXCLUSION LETTER

_____
Date

_____
work address of Engineer for
Indiana Department of Transportation

Att.: _____
Name, Project Engineer/Supervisor

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

cc: District Bridge Inspection Engineer
Environment, Planning and Engineering Division Chief
Project File

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.

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.

917.03 Source Approval Requirements. The Materials and Tests Division 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.

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.

(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.

(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 Materials and Tests Division 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:

(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;

(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.

Notice of removal from Certified status will be in written form, will be issued by the Materials and Tests Division, 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.