SECTION 712

STRUCTURAL STEEL CONSTRUCTION

712.1 Description. This work shall consist of the fabrication, inspection, erection and painting of bridges and structures made of structural steel and miscellaneous metals.

712.2 Material.

712.2.1 Except as amended by Sec 712.2.3, all material shall conform to Division 1000, Material Details and specifically as follows:

Item	**Section**
Shear Connectors	1037
Paint for Structural Steel	1045
	Specification
Structural Steel	AASHTO M 270, Grade 36 (250) ASTM A 709, Grade 36 (250)
Structural Low Alloy Steel	AASHTO M 270, Grade 50 (345) ASTM A 709, Grade 50 (345) AASHTO M 270, Grade 50W (345W) ASTM A 709, Grade 50W (345 W)
Quenched and Tempered Alloy Steel	AASHTO M 270, Grade 70W (485W) ASTM A 709, Grade 70W (485W) ASTM A 709, Grade 100/100W (690/690W)
Low Carbon Steel Bolts and Nuts	ASTM A 307
High Strength Bolts, Nuts and Washers	AASHTO M 164 (ASTM A 325)
Cold Finished Carbon Steel Shafting	AASHTO M 169 (ASTM A 108)
Carbon Steel Forgings	AASHTO M 102 (ASTM A 668) Class F
Alloy Steel Forgings	AASHTO M 102 (ASTM A 668) Class G
Gray Iron Castings	AASHTO M 105 (ASTM A 48) Class 50
Malleable Iron Castings	ASTM A 47
Carbon Steel Castings	AASHTO M 103 (ASTM A 27) Grade 485-275
Galvanized Coatings	AASHTO M 111 (ASTM A 123)
Lead for Bearing Pads	ASTM B 29

712.2.1.1 Bolts, nuts and washers specified to be galvanized shall be galvanized in accordance with the requirements of AASHTO M 232 (ASTM A 153), Class C or mechanically galvanized in accordance with the requirements of AASHTO M 298 (ASTM B 695), Class 55. Except for anchor bolts, galvanizing thickness shall not exceed 6 mils (150 µm).

712.2.1.2 Fasteners are not required to be galvanized when installed prior to the completion of shop blast cleaning.

712.2.1.3 Fit up and shipping bolts shall be coated to prevent corrosion where a finish coat will not be applied.

712.2.2 Falsework material shall be subject to the engineer's approval. Timber material shall be sound, in good condition, and free from defects that will impair their strength. Steel members shall be in good condition and of a shape and strength suitable for the purpose intended. Falsework piling shall be capable of withstanding driving to a depth sufficient to develop adequate bearing.

712.2.3 For structural steel, the contractor shall submit a copy of the certified mill test report giving the chemical analysis and results of physical tests on the material furnished. The mill test report shall also state the location of the mill where the molten metal was produced. Two copies of the mill test report will be required for material used in railroad structures. If the steel is produced outside the United States, the contractor shall submit a certified test report from a U. S. laboratory, approved by the State, showing specific results of chemical analysis and physical tests for each heat being furnished and stating that the material meets the specification requirements. Mill tests and laboratory reports shall be submitted for approval before any request is made for shop or field inspection. In addition, the State reserves the right to take samples for chemical analysis and physical tests from the fabricated steel delivered to the project site. Any delay caused by obtaining and analyzing samples from delivered steel shall not be cause for additional compensation nor extension of time for completion of the work.

712.2.3.1 Unless otherwise specified, the supplementary requirements of AASHTO M 270 (ASTM A 709) for Charpy V-notch impact tests in temperature zone 2 shall be mandatory where the contract documents indicate notch toughness is required for fracture critical or non-fracture critical components. Mill test reports shall include the results of Charpy V-notch testing and the impact serial numbers for fracture critical components.

712.2.4 High Strength Fastener Assemblies. In addition to the requirements of 712.2.3, high strength bolts, nuts and washers shall meet the following requirements. The contractor shall furnish a manufacturer's certification showing results of tests performed in accordance with these requirements. Identification in accordance with the appropriate AASHTO/ASTM specifications shall be maintained by container markings which shall match identifying numbers on the certifications and be traceable to the certified mill test reports. High strength fastener assemblies shall be galvanized unless used with unpainted weathering steel or specifically indicated otherwise by the contract documents. When high strength bolts are used with weathering steel, the fasteners shall be Type 3.

712.2.4.1 Bolts. All bolts shall be in accordance with AASHTO M164 (ASTM A325) and the following requirements. If the contractor elects to use load indicator bolts, a button head will be permitted. The type of head used shall be consistent throughout the entire structure, unless otherwise permitted.

712.2.4.1.1 Hardness required by AASHTO M164 (ASTM A325) for bolt diameters 1/2 inch (12.7 mm) to 1 inch (25.4 mm) inclusive shall be modified as noted below:

	Hardness Number			
Bolts Size, In. (mm)	**Brinnel**		**Rockwell C**	
	Min.	Max.	Min.	Max.
1/2 to 1 inch (12.7 to 25.4 mm)	248	311	24	33

712.2.4.1.2 Proof load tests in accordance with ASTM F606 Method 1 shall be performed. Minimum frequency of tests shall be in accordance with AASHTO M164 (ASTM A325).

712.2.4.1.3 Wedge tests on full size bolts in accordance with ASTM F606, paragraph 3.5 shall be performed. If bolts are to be galvanized, tests shall be performed after galvanizing. Minimum frequency of tests shall be in accordance with AASHTO M164 (ASTM A325).

712.2.4.1.4 The thickness of the zinc coating of galvanized bolts shall be measured on the wrench flats or top of the bolt head.

712.2.4.2 Nuts. All nuts shall be in accordance with AASHTO M292 (ASTM A194) as applicable or AASHTO M291 (ASTM A563) except as follows.

712.2.4.2.1 Nuts to be hot dip or mechanically galvanized shall be heat treated grade 2H, DH or DH3.

712.2.4.2.2 Ungalvanized nuts shall be grades 2, C, D or C3 with a minimum Rockwell hardness of 89 HRB or Brinell hardness 180 HB, or heat treated grades 2H, DH or DH3.

712.2.4.2.3 Nuts to be galvanized shall be tapped oversize the minimum amount required for proper assembly. The amount of overtap in the nut shall be such that the nut will assemble freely on the bolt in the coated condition and shall be in accordance with the mechanical requirements AASHTO M291 (ASTM A563) and the rotational-capacity test. The overtapping requirements of ASTM A563 shall apply except these limits shall be considered maximum values instead of the minimum, as it is currently shown.

712.2.4.2.4 All galvanized nuts including ASTM A194 nuts shall meet the supplementary requirements of ASTM A563. Galvanized nuts shall be lubricated with a lubricant containing a dye of any color that contrasts with the color of the galvanizing.

712.2.4.2.5 Proof load tests in accordance with ASTM F606 shall be performed. Minimum frequency of tests shall be in accordance with AASHTO M291 (ASTM A563) or AASHTO M292 (ASTM A194). If nuts are to be galvanized, tests shall be performed after galvanizing, overtapping and lubricating.

712.2.4.2.6 The thickness of the zinc coating on the galvanized nuts shall be measured on the wrench flats.

712.2.4.2.7 When Type 3 fasteners are specified for use with weathering steel, nuts shall be in accordance with AASHTO M291 (ASTM A563) and shall be grades C3 or DH3.

712.2.4.3 Washers. All washers shall be in accordance with AASHTO M293 (ASTM F436) and the following requirements.

712.2.4.3.1 Hardness testing shall be performed on galvanized washers. The coating shall be removed prior to taking hardness measurements.

712.2.4.3.2 The thickness of the zinc coating on galvanized washers shall be measured.

712.2.4.4 Rotational-Capacity Tests. Rotational-capacity tests shall be performed on all black or galvanized (after galvanizing) bolt, nut and washer assemblies by the manufacturer or distributor prior to shipping. Washers shall be part of the test regardless if they are not required as part of the installation procedure.

712.2.4.4.1 Except as modified herein, the rotational-capacity test shall be performed in accordance with AASHTO M164 (ASTM A325).

712.2.4.4.2 Each combination of bolt production lot, nut lot and washer lot shall be tested as an assembly. Where washers are not required by the installation procedures, washers need not be included in the lot identification.

712.2.4.4.3 A rotational-capacity lot number shall be assigned to each combination of lots tested.

712.2.4.4.4 The minimum frequency of testing shall be two assemblies per rotational-capacity lot.

712.2.4.4.5 The bolt, nut and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.

712.2.4.4.6 The minimum rotation, from a snug tight condition (10% of the specified proof load), shall be as follows:

Bolt Length	**Rotation**
< 4 Diameters	240° (2/3 turn)
> 4 Diameters and < 8 Diameters	360° (1 turn)
> 8 Diameters	480° (1 1/3 turn)

712.2.4.4.7 The tension reached at the above rotation shall be equal to or greater than 1.15 times the required installation tension. The installation tension and the tension for the turn test for A325 bolts shall be as follows:

Diameter (In.)	**1/2**	**5/8**	**3/4**	**7/8**	**1.00**	**1-1/8**	**1-1/4**	**1-3/8**	**1-1/2**
Req. Installation Tension (kips)	12	19	28	39	51	56	71	85	103
Turn Test Tension (kips)	14	22	32	45	59	64	82	98	118

Diameter (mm)	**12.7**	**15.9**	**19.0**	**22.2**	**25.4**	**28.6**	**31.8**	**34.9**	**38.1**
Req. Installation Tension (kN)	53	85	125	173	227	249	316	378	458
Turn Test Tension (kN)	62	98	142	200	262	285	365	436	525

712.2.4.4.8 After the required installation tension has been exceeded, one reading of tension and torque shall be taken and recorded. The torque value shall be as follows:

$$\text{Torque} \leq 0.25\,PD$$

Where:

Torque = measured torque, foot-pounds (N-m)
P = measured bolt tension, pounds (N)
D = bolt diameter, feet (m)

712.2.4.4.9 Bolts that are too short to test in a Skidmore-Wilhelm Calibrator may be tested in a steel joint. The maximum torque requirement shall be computed using a value of P equal to the turn test tension shown in Sec 712.2.4.4.7.

712.2.4.5 Reporting. The results of all tests, including zinc coating thickness, required herein and in the applicable AASHTO/ASTM specifications shall be recorded on the appropriate document. Location and date of tests performed shall be reported on the appropriate document.

712.2.4.6 Witnessing. The tests need not be witnessed by an inspection agency. The manufacturer or distributor performing the tests shall certify the results are accurate.

712.2.4.7 Documentation for High Strength Fastener Assemblies.

712.2.4.7.1 Mill Test Reports (MTR). An MTR shall be furnished for all mill steel used in the manufacture of the bolts, nuts or washers. The MTR shall indicate the place where the material was melted and manufactured.

712.2.4.7.2 Manufacturer Certified Test Reports (MCTR). The manufacturer of the bolts, nuts and washers shall furnish the MCTR for the item furnished. Each MCTR shall show the relevant information required in accordance with Sec 712.2.4.5. The manufacturer performing the rotational-capacity test shall include on the MCTR:

(a) The lot number of each of the items tested.

(b) The rotational-capacity lot number as required in Sec 712.2.4.4.3.

(c) The results of the tests required in Sec 712.2.4.5.

(d) The pertinent information required in Sec 712.2.4.4.2.

(e) A statement that MCTR for the items are in conformance to this specification and the applicable AASHTO/ASTM specifications.

(f) The location where the bolt assembly components were manufactured.

712.2.4.7.3 Distributor Certified Test Reports (DCTR). The DCTR shall include MCTR for the various bolt assembly components. The rotational-capacity test may be performed by a distributor in lieu of a manufacturer and reported on the DCTR. The DCTR shall show the following:

(a) The results of the tests required in Sec 712.2.4.5.

(b) The pertinent information required in Sec 712.2.4.4.2.

(c) The rotational-capacity lot number as required in Sec 712.2.4.4.3.

(d) A statement that the MCTR are in accordance with this specification and the applicable AASHTO/ASTM specifications.

(e) Certification of galvanizing from the galvanizing supplier shall be in accordance with Sec 712.2.1.1.

712.2.4.8 Shipping of High Strength Fastener Assemblies. Bolts, nuts and washers, where required, from each rotational-capacity lot shall be shipped together in proportionate quantities for use in the same containers. If there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. Each shipping container shall be permanently marked by the manufacturer or distributor with the rotational-capacity lot number such that identification will be possible at any stage prior to installation.

The appropriate MTR, MCTR or DCTR shall be supplied in accordance with the contract documents.

712.2.5 For cast steel, the foundry shall furnish a certified copy of foundry reports giving the chemical analysis and results of physical tests on the material from each heat. These reports shall be submitted for approval of material being furnished before any required machine work is done on the castings.

712.2.6 For gray iron castings, the foundry shall furnish one finished tension test specimen in accordance with AASHTO M 105 (ASTM A 48) from each heat. The required machine work shall not proceed until material being furnished has been approved. If cast steel is furnished in lieu of gray iron, the minimum tensile strength shall be 50,000 pounds per square inch (345 MPa).

712.2.7 Machine finished surfaces shall be coated as soon as practicable, after being inspected and accepted and before being removed from the shop or placed in the open, with an application of one of the products qualified under Military Specifications MIL-C-11796 (Corrosion Preventive, Petrolatum, Hot Application). Other approved coatings may be used. In lieu of this coating, surfaces not in full contact may be given a shop coat of the primer specified for the paint system to be used.

712.2.8 Identification of Metals. The steel shall be stamped or stenciled and color striped with paint at the mill. Heat numbers shall be steel stamped or stenciled with paint at the mill. Separate markings and color codes shall be in accordance with AASHTO M 160 (ASTM A 6). The characteristic color stripes shall be placed on each part cut from the mill piece. For steels not covered by AASHTO M 160 (ASTM A 6), the fabricator shall furnish the engineer the color coding in writing before beginning fabrication. Heat numbers shall be painted on all principal pieces and these pieces shall be so noted on the shop drawings. Principal pieces for this requirement shall include all beams, flanges, webs, splice plates, cover plates, bearings, bearing stiffener plates, load bearing members of end diaphragms, pin plates, hanger plates and others as may be directed by the engineer. Principal pieces shall also include individual plates of all truss members, truss gusset plates, splice plates and floorbeam connection angles. The color code and heat number markings shall be placed on the material so as to be visible throughout the work of fabrication. Loss of identification on pieces or items will be cause for rejection of the pieces or items.

712.2.8.1 Principal pieces requiring identification shall also include components of fracture critical members. Traceability of both heat numbers and impact serial numbers shall be maintained for fracture critical members and attachments.

712.2.8.2 Unless otherwise indicated in the contract documents, steel plates for main members and splice plates for flanges and main tension members shall be cut and fabricated so the primary direction of rolling is parallel to the direction of the principal tensile or compressive stresses. The direction of rolling shall be maintained for all principal pieces during fabrication.

712.2.9 Steel Stamping. Any metal die stamping of match marks and erection marks in structural steel members shall be limited to a position in the end 1 1/2 inches (38 mm) of flange plates and flange splice plates, the middle third of web plates and the outside edge of the middle third of web splice plates. Metal die stamping at other locations or for other purposes may be approved by the engineer provided low stress dies are used. Low stress dies are those manufactured to produce impressions that are rounded at the bottom rather than sharp edged. The dies shall be lightly struck to produce the minimum impression that can be clearly seen in the absence of paint and mill scale. Metal die stamping on pin plates and hanger plates will not be permitted.

712.3 Fabrication and Inspection.

712.3.1 Quality Assurance Inspection. The engineer will be responsible for QA inspection to assure the quality of the fabricated material. QA inspection by the engineer shall not relieve the contractor of the responsibility to provide fabricated structural steel items in accordance with the contract documents. Sufficient QC, as necessary to assure work being performed conforms to the contract documents, shall be considered the responsibility of the contractor and fabricator. Following adequate notification that QC inspections and testing by the fabricator have been performed, QA inspection will be at the option of the engineer. Regardless of the location and degree of QA inspection, material and workmanship not meeting specified performance criteria or conforming to the contract documents or recognized good practice may be rejected at any time prior to final acceptance of the work.

712.3.1.1 QA inspection of fabricated material will ordinarily be made in the shop for fabricating shops within the 48 contiguous States and for shops outside the U. S. but within 1000 miles (1600 km) of Jefferson City. High strength bolts, nuts and washers shall be presented for sampling at the fabrication shop performing the primary fabrication or at a location agreed to by Project Operations. In some cases QA inspection in the fabrication shop may be waived and inspection made when the fabricated material is delivered to the project site. All costs of QA inspection at fabricating shops located both outside the 48 contiguous States and more than 1000 miles (1600 km) from Jefferson City, shall be borne by the contractor. In such cases, the contractor will be charged with transportation costs and expenses of QA inspectors for trips made from Jefferson City to locations to which they must travel for shop inspection work. These transportation costs and expenses of QA inspectors will be deducted by the Commission from monies due the contractor.

712.3.1.2 Regardless of where material is inspected, some QA inspection prior to actual fabrication will normally be required. If failures occur in the qualification of welders, welding procedures or welding processes that require additional inspection or additional witnessing, all costs and expenses incurred solely for the additional inspection or witnessing shall be borne by the contractor.

712.3.1.3 The engineer shall be notified in advance of the beginning of the shop fabrication so a QA inspector may be present if so desired. Notification shall be made sufficiently in advance to allow the QA inspector to make travel arrangements. As a minimum, four working days notice shall be provided.

712.3.1.4 The engineer shall have full access to all parts of the shop or project site where material is being fabricated or assembled, and shall be provided with every reasonable facility for determining the character of material and workmanship. All trusses, plate girders and continuous I-beams shall be assembled for inspection and be in a position that will permit the inspection of all parts. QA inspection of the assembly will be at the option of the engineer. If QA inspection of the fabricated material is performed at the project site, the contractor may be required to assemble the material for inspection prior to erection. The additional work of handling and assembly for QA inspection at the project site, any delay or additional costs caused by the inspection, required repairs or refabrication, securing samples for chemical analysis and physical tests, repair of areas where samples were removed or nondestructive testing of all repairs shall not be cause for additional compensation nor extension of time for completing the work.

712.3.1.5 An enclosed office area for the exclusive use of the engineer, having not less than 120 square feet (11 m^2) of floor space shall be provided at the location of QA inspection unless otherwise approved by the engineer. The area shall be weatherproof, secure, insulated and lighted. The area shall also be ventilated, heated and air conditioned with systems capable

of maintaining an ambient air temperature of 72 F (22 C). Electric outlets with 110-120 volt, 60 Hz current and a telephone with outside line and inter-plant capabilities shall be provided. Office furniture consisting of a desk a minimum of 30 inches x 60 inches (750 mm x 1500 mm) with drawers, a swivel desk chair with arms and a storage/filing cabinet with lock hardware and key shall be provided. All office furniture shall be approved by the engineer. Should any furniture become unsatisfactory, it shall be promptly repaired or replaced to the satisfaction of the engineer. Parking shall be provided near the office with direct accessibility at any time the shop is in operation. No direct payment will be made for furnishing and maintaining an acceptable office area for QA inspection.

712.3.1.6 All structural steel fabricators performing work for the following listed components of steel structures shall be certified prior to the start of fabrication under the appropriate category of the American Institute of Steel Construction (AISC) Quality Certification Program as follows:

(a) Fabricators of main load-carrying components of welded plate girders, box girders, trusses and arches shall be certified under the AISC Major Steel Bridges category (Cbr). Fabricators of fracture critical members shall be certified under this category with the additional endorsement for fracture critical capability.

(b) Fabricators of main load-carrying components for simple span or continuous rolled beam bridges and POT bearings shall, as a minimum, be certified under the AISC Simple Steel Bridge Structures category (Sbr).

(c) Fabricators of overhead sign trusses, temporary bridges and steel bearings shall, as a minimum, be certified under the AISC Conventional Steel Buildings category (Sbd).

(d) AISC certification will not be required for manufacturers of simple laminated or elastomeric bearing assemblies.

712.3.2 Shop Drawings. Shop drawings for structural steel and miscellaneous metals will be required, and shall be prepared in strict accordance with the design details shown on the plans. If details are lacking, they shall be supplied and shall conform to the design plans and specifications. All drawings shall be clear and complete, and shall be thoroughly checked before submittal. Four sets of prints of the shop drawings for railroad structures, and two sets for other structures shall be submitted for approval. The prints submitted shall be legible and have distinct details of sufficient contrast to be suitable for microfilming. Prints which do not have the desired clarity and contrast will be returned for corrective action. One set of these prints will be returned marked reviewed or approved subject to the corrections noted. The contractor shall promptly make the necessary corrections and resubmit for final approval. When shop drawings are finally approved, the contractor shall furnish as many additional prints as may be requested. Reproductions on cloth or film of the original shop drawings will be required for railroad structures and shall be delivered to the engineer prior to completion of the work. The approval of shop drawings will cover only the general design features, and in no case shall this approval be considered to cover errors or omissions in shop details. The contractor shall be responsible for the accuracy of the shop drawings, the fabrication of material and the fit of all connections. The contractor shall also bear the cost of all changes in the work in erection caused by errors in shop drawings and for any changes in fabrication necessary for satisfactory erection. After shop drawings have been approved, no changes in dimensions or substitutions of sections shall be made without written approval. Shop drawings shall be revised to show any authorized changes and the required number of prints shall be furnished the engineer.

712.3.2.1 Shop drawings for fabricators located outside the 48 contiguous States, whether marked approved or approved subject to the corrections noted, will be returned to the

contractor, and it shall be his responsibility to transmit them to the fabricator for further handling. Should such fabricator also be the contractor, all prints will be returned to the office located on the project.

712.3.2.2 Shop drawings shall be completely titled in accordance with the contract plans and shall pertain to only a single structure.

712.3.2.3 All welding procedures to be used shall be prepared by the manufacturer, contractor or fabricator as a written procedure specification and two copies shall be submitted prior to submitting shop drawings. The shop drawings submitted for approval shall indicate the welding procedure to be used for each joint.

712.3.2.4 By submission of shop drawings, the contractor represents to the Commission that all materials, field measurements, construction requirements, performance criteria and similar data have been verified. By submission, the contractor further represents that the shop drawings have been coordinated and verified with the details of the work to be performed by other fabricators and entities on the project. No allowance for additional costs or delays will be made to the contractor for incorrect fabrication as a result of failure to coordinate or perform these verifications.

712.3.3 Fabrication. Fabrication of all parts of the structure shall be carefully done in strict accordance with the approved shop drawings.

712.3.3.1 Straightening of any deformed structural material shall be performed by non-injurious methods prior to being laid off, punched or otherwise worked in the shop. Sharp kinks and bends will be cause for rejection.

712.3.3.2 Holes for connections of main members shall be subpunched or subdrilled, and reamed while assembled in the shop or may be drilled from the solid with main members, and each splice plate fully assembled in their final erected positions. Holes for floor beams and framed stringer connections shall be drilled or reamed to a steel template of sufficient thickness to center the drill accurately, and all members to be secured through the same group of holes shall be drilled or reamed from the same template. Holes may be punched full size in secondary members such as lateral, longitudinal and sway bracing, lacing bars, stay plates and diaphragms.

712.3.3.3 Subpunched holes for bolts having diameters greater than 3/4 inch (19 mm) shall be punched 3/16 inch (5 mm) smaller than the nominal diameter of the bolt. For bolts having a diameter of 3/4 inch (19 mm), the holes shall be punched 11/16 inch (18 mm) in diameter. For bolts having diameters of 5/8 inch (16 mm) or less, the holes shall be punched full size and spear reamed. The punch and die shall have the same relative sizes as specified in Sec 712.3.3.6 for full size punched holes. After assembling, subpunched or subdrilled holes shall be reamed with tapered reamers to a diameter not more than 1/16 inch (1.5 mm) larger than the nominal diameter of the bolt.

712.3.3.4 Holes drilled full size from the solid shall be 1/16 inch (1.5 mm) larger than the nominal diameter of the bolt.

712.3.3.5 Reaming or drilling full size from the solid shall be done while the truss, girder, continuous I-beam or other component as noted, is assembled, either in an upright position or on its side, properly adjusted for camber and sweep and after the connecting parts have been firmly fastened together. A minimum of one full span, from bearing to bearing, shall be fully assembled before reaming or drilling full size shall begin. Connecting parts assembled in the shop for the purpose of reaming or drilling holes for field or shop connections shall not be interchanged or reversed and shall be matchmarked. A diagram showing such marks shall be

detailed on the shop drawings. Burrs resulting from reaming, drilling or punching shall be removed. All connections shall be disassembled after drilling or reaming to make these holes accessible for deburring. Required cleaning and painting shall be done after this disassembly. Reamed, drilled or punched holes shall be round and perpendicular to the member. Any hole out of round more than 1/16 inch (1.5 mm) shall be cause for rejection of the plate. Eighty-five percent of the holes in any group shall not show an offset greater than 1/32 inch (1 mm) between adjacent thicknesses of metal after reaming or drilling. All of the holes shall be drilled or reamed and aligned so that a bolt of the specified diameter will enter the hole, and the head and nut will seat on the metal before tensioning.

712.3.3.6 Punching full size holes for bolts in carbon steel may be done if the thickness of the metal does not exceed the specified diameter of the bolt. For carbon steel thicker than the specified diameter of the bolt, the holes shall be subpunched and reamed or drilled from the solid. Punching full size holes in alloy and low alloy steels may be done in material 5/8 inch (16 mm) thick or less. Holes in alloy or low alloy steel over 5/8 inch (16 mm) thick shall be subpunched and reamed or drilled from the solid. Except for special cases, the diameter of the punch for full size holes shall be not more than 1/16 inch (1.5 mm) greater than the diameter of the bolt, and the diameter of the die shall not be more than 1/16 inch (1.5 mm) greater than the diameter of the punch. Punching shall be done accurately and there shall be no drifting to enlarge unmatched holes.

712.3.3.7 All welding, oxygen cutting, shearing and clipping and dimensional tolerances shall be in accordance with requirements set forth in the ANSI/AASHTO/AWS D1.5-95, Bridge Welding Code. Tubular steel structures shall be governed by the current edition of the AWS D1.1, Structural Welding Code - Steel, in effect at the time of the contract, unless otherwise indicated. Aluminum structures shall be governed by the current edition of the AWS D1.2, Structural Welding Code - Aluminum, except as amended by Sec 903, unless otherwise indicated.

712.3.3.7.1 The following modifications to the ANSI/AASHTO/AWS D1.5-95, Bridge Welding Code (AWS), shall apply:

712.3.3.7.1.1 AWS Sec 1.3 Paragraph 1.3.2 - Paragraph 1.3.2 shall be replaced with the following:

No electroslag or electrogas welding shall be used.

712.3.3.7.1.2 AWS Sec 1.3 Paragraph 1.3.4 - Paragraph 1.3.4 shall be replaced with the following:

The gas metal arc welding process shall not be used on any structural components of bridges. Approved gas metal arc processes may be used for incidental, non-structural components as may be specifically approved by the engineer. Tack welding with an approved gas metal arc process is permissible for joints that will subsequently be welded using an approved submerged arc automatic welding process.

712.3.3.7.1.3 AWS Sec 1.3 Paragraph 1.3.7 - A new Paragraph 1.3.7 shall be added as follows:

All primary shop welds shall be made by approved submerged arc automatic welding processes. The automatic welding process shall be one in which the wire or electrode feed, speed of travel and guidance are all mechanically controlled. Noncompliance with this requirement will be cause for rejection of the welded material unless prior approval is granted by the engineer for welding the specified joints by the use of other processes. The automatic welding process requirement for primary shop welds shall be shown on the shop drawings for

each joint. Primary shop welds are defined as flange and web butt welded splices in I-beams, box members and plate girders, plate girder or box flange to web fillet welds and cover plate to flange fillet welds.

712.3.3.7.1.4 AWS Sec 2.7 Paragraph 2.7.1.1 - Paragraph 2.7.1.1 shall be replaced with the following:

The minimum fillet weld size, except for fillet welds used to reinforce groove welds, shall be as shown in the following table or as calculated using procedures established to prevent cracking in accordance with Paragraph 4.2.2. In both cases, the minimum size applies if it is sufficient to satisfy design requirements.

Material Thickness of Thicker Part Joined, in. (mm)	Minimum Size of Fillet Weld* in. (mm)
To 1/2 (13) inclusive	3/16 (5)**
Over 1/2 (13) to 3/4 (19)	1/4 (6)**
Over 3/4 (19) to 1 1/2 (38)	5/16 (8)**
Over 1 1/2 (38) to 2 1/4 (57)	3/8 (10)
Over 2 1/4 (57) to 6 (150)	1/2 (14)
Over 6 (150)	5/8 (16)

*Except that the weld size need not exceed the thickness of the thinner part joined.
**Single pass welds must be used.

712.3.3.7.1.5 AWS Sec 3.2 Paragraph 3.2.2.2 (4) - A new Paragraph 3.2.2.2 (4) shall be added as follows:

Quenched and tempered steel plate may be thermally cut using good shop practices and provided sufficient preheating is applied according to the steel producer's written recommendations. Procedures for thermal cutting of quenched and tempered steel plate, along with the steel producer's written report, shall be submitted to the Bridge Division for approval prior to the start of such work.

712.3.3.7.1.6 AWS Sec 3.2 Paragraph 3.2.3.4 - Paragraph 3.2.3.4 shall be replaced with the following:

The corrective procedures described in Table 3.1 shall not apply to discontinuities in rolled base-metal surfaces. Such discontinuities may be corrected by the fabricator in accordance with the provisions of ASTM A 6 (AASHTO M 160) except that repair by welding will be permitted only when approved by the engineer. Approval will be limited to areas where there will be less than the maximum design stress in the finished structure. When surface imperfections in alloy, low alloy and carbon steel plates are repaired by grinding, they shall have edges faired to the plate surface with a slope not exceeding 1 in 10.

712.3.3.7.1.7 AWS Sec 3.4 Paragraph 3.4.6 - Paragraph 3.4.6 shall be replaced with the following:

All shop splices in each component part of a cover-plated beam or built-up member shall be made and all required nondestructive testing completed and approved by the engineer before the component part is welded to other component parts of the member. Long members or member sections may be made by shop-splicing subsections, each made in accordance with this subsection (see 9.17). All shop splices shall be made using full penetration welds that fully develop the capacity of the original member. Additional shop splices required due to length limits of available material may be used if they are detailed on the shop drawings and are placed at locations approved by the engineer. No additional payment will be made for any

additional shop splices placed in the members at the option of the contractor, including shop splices that may be required as a result of material limitations.

712.3.3.7.1.8 AWS Sec 3.5 Paragraph 3.5.1.3 and Table 3.2 - Paragraph 3.5.1.3 shall be replaced with the following, Table 3.2 shall be deleted and Table 3.3 shall remain in effect:

For welded beams or girders, except when the top flange is embedded in concrete without a designed concrete haunch, regardless of cross section, the allowable variation from required camber at shop assembly (for drilling holes for field splices or preparing field welded splices) shall be as follows:

at midspan

-0, +3/4 inch (+19 mm) for all spans

at supports

0 for end supports, $\pm$1/8 inch ($\pm$3 mm) for interior supports

at intermediate points

$$-0, + \frac{4(a)b(1-a/S)}{S}$$

where:

a = distance in feet (meters) from inspection point to nearest support

S = span length in feet (meters)

b = 3/4 inch (19 mm)

See Table 3.3 for tabulated values.

For members with the top flange embedded in concrete and no designed concrete haunch, the allowable variation from required camber at shop assembly (for drilling holes for field splices or preparing field welded splices) shall be as follows:

at midspan

-0, +3/4 inch (+19 mm) for spans $\geq$ 100 feet (30 m)
-0, +3/8 inch (+9.5 mm) for spans < 100 feet (30 m)

at supports

0 for end supports, ? 1/8 inch (? 3 mm) for interior supports

at intermediate points

$$-0, + \frac{4(a)b(1-a/S)}{S}$$

where:

a = distance in feet (meters) from inspection point to nearest support

S = span length in feet (meters)
b = 3/4 inch (19 mm) for spans $\geq$ 100 feet (30 m)
b = 3/8 inch (9.5 mm) for spans < 100 feet (30 m)

See Table 3.3 for tabulated values.

Regardless of how the camber is shown on the detail drawings, the sign convention for the allowable variation shall be plus (+) above, and minus (-) below, the detailed camber shape.

These specifications also apply to an individual member when no field splices or shop assembly is required.

Camber measurements shall be made in the no-load condition.

712.3.3.7.1.9 AWS Sec 3.5 Paragraph 3.5.1.8.1 - A new Paragraph 3.5.1.8.1 shall be added as follows:

The maximum permissible variation from specified width for rolled or burned flange plates shall be -1/8 inch to +3/8 inch (-3 mm to +9.5 mm).

712.3.3.7.1.10 AWS Sec 3.5 Paragraph 3.5.1.9 - Paragraph 3.5.1.9 shall be replaced with the following:

The bearing ends of bearing stiffeners shall be flush and square with the web and shall have at least 75 percent of this area in contact with the inner surface of the flanges. The remaining 25 percent of the area of the bearing stiffener shall be within 0.010 inch (0.25 mm) of the inner surface of the flanges. When bearing against a steel base or seat, all steel components shall fit within 0.010 inch (0.25 mm) for 75 percent of the projected area of web and stiffeners and not more than 1/32 inch (0.8 mm) for the remaining 25 percent of the projected area. Girders without stiffeners shall bear on the projected area of the web on the outer flange surface within 0.010 inch (0.25 mm). The included angle between web and flange shall not exceed 90 degrees in the bearing length. The top surface of a flange or shelf plate supporting a steel bearing rocker shall be considered a flat surface with a tolerance of 0.003 inch per inch (0.003 mm/mm) in any direction over the projected area of the rocker. The top surface of a flange or shelf plate in direct contact with elastomeric bearings shall not deviate from a true plane surface by more than 1/16 inch (1.5 mm).

712.3.3.7.1.11 AWS Sec 3.5 Paragraph 3.5.1.16 - A new Paragraph 3.5.1.16 shall be added as follows:

Permissible variation in length of assembled beams or girders between the centerline of bearing devices shall not exceed plus or minus 1/4 inch (6 mm) for any one span or plus or minus 3/8 inch (9.5 mm) for any two or more spans within the assembled unit. The actual centerline of any bearing device shall lie within the thickness of the bearing stiffener.

712.3.3.7.1.12 AWS Sec 3.7 Paragraph 3.7.2.5 - A new Paragraph 3.7.2.5 shall be added as follows:

If, after two repairs to the same area of a weld requiring radiographic quality, there is any part of the original defect remaining or there is a new rejectable indication, the total joint shall be cut apart, all deposited weld metal removed, joint preparation made and the total joint rewelded. For welded joints requiring less than 100 percent radiographic quality, a third weld repair to an area may be made only with the approval of the engineer.

712.3.3.7.1.13 AWS Sec 3.7 Paragraph 3.7.2.6 - A new Paragraph 3.7.2.6 shall be added as follows:

The gas metal arc welding process shall not be used for the repair of welds except when repairing welds made with the GMAW process.

712.3.3.7.1.14 AWS Sec 5.21 Paragraph 5.21.6.2 - A new Paragraph 5.21.6.2 shall be added as follows:

Any cost involved in qualifying welders, welding operators and tackers, including all costs of material, finishing of test specimens, the physical testing of finished specimens and any radiography required, shall be borne by the contractor. Required radiography and physical testing of finished specimens shall be performed at test facilities approved by the engineer.

712.3.3.7.1.15 AWS Sec 6.6 Paragraph 6.6.5 - Paragraph 6.6.5 shall be replaced with the following:

If nondestructive testing, not specified in the original contract agreement, is subsequently requested by the engineer, the contractor shall perform any requested testing or shall permit any requested testing to be performed. Handling, surface preparation, repair welds and any nondestructive testing requested by the engineer, as a result of weld repair, shall be at the expense of the contractor.

712.3.3.7.1.16 AWS Sec 6.7 Paragraphs 6.7.1, 6.7.1.1 and 6.7.1.2 - Paragraphs 6.7.1, 6.7.1.1 and 6.7.1.2 shall be replaced with the following:

Radiographic inspection will be required for areas of both shop and field butt welds as specified herein. One hundred percent inspection will be required for flanges of rolled beams and girders and 100 percent of transverse butt welds in webs for a distance of not less than 1/6 of the web depth from each flange and 25 percent of the remainder of the web depth. At least 1/3 of the length of all longitudinal web splices shall be radiographed at even intervals throughout the length of the splice. When a rejectable defect is found by radiography in any partially tested joint, either initially or in a later additional radiograph, tests shall be made adjacent to and on either side of the rejectable test area. If a rejectable defect is found in any of these additional areas, then 100 percent of vertical web splices and an additional 10 percent of total weld length in longitudinal web splices shall be tested. The location of these additional test areas shall be as directed by the engineer.

712.3.3.7.1.17 AWS Sec 6.10 Paragraph 6.10.3.4 - A new Paragraph 6.10.3.4 shall be added as follows:

Edge blocks shall be used when radiographing butt welds greater than 1/2 inch (13 mm) in thickness. The edge blocks shall have a length sufficient to extend beyond each side of the weld centerline for a minimum distance of 2 inches (50 mm) and shall have a thickness equal to the thickness of the weld, plus or minus 1/16 inch (1.5 mm). The minimum width of the edge blocks shall be not less than 1 inch (25 mm). The edge blocks shall be centered on the weld with a snug fit against the plate being radiographed, allowing no more than 1/16 inch (1.5 mm) gap. Edge blocks shall be made of radiographically clean steel and the surface shall have a finish of ANSI 125 or smoother (refer to ANSI/AWS D1.1-98 Structural Welding Code - Steel, Sec 6.17, Paragraph 6.17.13 and Figure 6.15).

712.3.3.7.1.18 AWS Sec 6.10 Paragraph 6.10.11.2 - Paragraph 6.10.11.2 shall be replaced with the following:

If the greatest and least thickness of a weld connecting parts of different thickness cannot be rendered with adequate contrast on a single film with a single exposure, a dual film, or dual exposure technique shall be used to obtain suitable density for both the greatest and the least thickness of the weld.

712.3.3.7.1.19 AWS Sec 6.12 Paragraph 6.12.4 - A new Paragraph 6.12.4 shall be added as follows:

After completion of all radiographic inspection, the contractor shall submit to the engineer one set of shop drawing details showing the location and identification numbers of all radiographs taken.

712.3.3.7.1.20 AWS Sec 9.18 Paragraph 9.18.3 - A new paragraph 9.18.3 shall be added as follows:

Sheared edges of plates not to be welded that are more than 5/8 inch (16 mm) thick and carrying calculated stress shall be planed to a depth of 1/4 inch (6 mm).

712.3.3.7.1.21 AWS Sec 9.20 - Sec 9.20 shall be replaced with the following:

Temporary welds shall be subject to the same WPS requirements as final welds. They shall be removed unless otherwise permitted by the engineer. When they are removed, the surface shall be made flush with the original surface. Unless previously approved in writing by the engineer, there shall be no temporary welds for fabrication, transportation, erection or other purposes on main members except at locations more than 1/6 the depth of the web from the flanges of beams and girders. There shall be no temporary welds in tension zones of members of quenched and tempered steels. Temporary welds at other locations shall be shown on shop drawings and shall be made with approved consumables. Removal of temporary welds shall conform to the requirements of Paragraphs 3.3.7.3 and 3.3.7.4.

712.3.3.7.1.22 AWS Sec 9.21 Paragraph 9.21.2.1 - Paragraph 9.21.2.1 shall be replaced with the following:

For any welds, the greatest dimension of any porosity or fusion type discontinuity that is 1/16 inch (1.5 mm) or larger in greatest dimension shall not exceed the size, B, indicated in Figure 9.4 for the effective throat or weld size involved. The distance from any porosity or fusion type discontinuity described above to another such discontinuity, to an edge or to the toe or root of any intersecting flange-to-web weld shall not be less than the minimum clearance allowed, C, indicated in Figure 9.4 for the size of discontinuity under examination.

712.3.3.7.1.23 AWS Sec 9.21 Paragraph 9.21.2.2 and Figure 9.5 - Delete paragraph 9.21.2.2 and Figure 9.5.

712.3.3.7.1.24 AWS Sec 9.21 Paragraph 9.21.3.1 - Paragraph 9.21.3.1 shall be replaced with the following:

Welds that are subject to ultrasonic testing in addition to visual inspection shall conform to the requirements of Table 9.1.

712.3.3.8 Milled joints shall be dressed accurately and smoothly to obtain contact throughout the depth and thickness of all component parts. The finishing of such surfaces shall be done after welding of the members is completed.

712.3.3.9 Calibrated Tapes. When the contract involves fabrication of a bridge with a bearing-to-bearing span of 100 feet (30 m) or more, certifications and identifying numbers of

calibrated measuring tapes or numbered tapes matched to a calibrated master shall be submitted. Certification of the measuring tape to be used or certification of the master from which the tape was matched shall be traceable to the U. S. National Bureau of Standards. Certification of tapes for shop use shall be renewed at least every two years.

712.3.3.9.1 Field Welders. Field welders shall be qualified by a test facility with an established accredited AWS Certified Welder Program as defined in AWS Standard QC 4-89 or by an independent testing laboratory furnished by the contractor. If specimens are to be tested at an independent testing laboratory, they shall be witnessed and properly documented by the engineer. All tested specimens and radiographs, along with the laboratory's test report certifying the test results, shall be delivered to the engineer for final acceptance or rejection. If the field welder was tested and certified by a facility with an established accredited AWS Certified Welder Program as defined in AWS Standard QC 4-89, the tested specimens and radiographs will not be subject to the engineer's review. A copy of the welder's certification from the AWS test facility shall be delivered to the engineer.

712.3.3.9.2 Qualification cards will be issued by the engineer for field welders working on Commission projects. No individual may weld on a MoDOT project unless the engineer can confirm they have continued to weld on Commission projects with the processes and in the positions for which they were initially certified without an interruption exceeding twelve months. The engineer may require recertification if there is a specific reason to question the welder's ability.

712.3.3.10 Connection angles for floor beams and stringers shall be flush and shall be correct as to position and length of member. If milling is required, not more than 1/16 inch (1.5 mm) shall be removed from the thickness of the angles.

712.3.3.10.1 Longitudinal girder web stiffeners shall be a single length insofar as possible. If more than a single length is necessary, such lengths shall be joined by a full penetration butt weld. The location of these butt welds shall be shown on the shop drawings for each joint and be subject to approval by the engineer. Runoff plates in compliance with AWS Section 9.25 shall be used. The welds shall be radiographically tested and accepted in accordance with the requirements of AWS Section 9.25 prior to being attached to the web.

712.3.3.11 Pins. Pins shall be furnished true to size and shall be straight, smooth and free from flaws. They shall be provided with hexagonal chamfered nuts. The screw ends shall be sufficiently long to permit burring the threads when members are connected. Pilot and driving nuts shall be furnished for each size of pins where required. Threads for all pins and bolts shall conform with the ANSI B1.1 Free Fit - Class 2 Series except that when recessed nuts are specified, pin ends requiring a threaded diameter of 1 3/8 inches (35 mm) or more shall have six threads per inch (25 mm). If standard nuts are specified for this size pin, a minimum of four threads to the inch (25 mm) shall be used.

712.3.3.11.1 Pin Holes. Pin holes shall be bored true to size, smooth and straight, at right angles to the axis of the member, and parallel with each other. The boring shall be done after the member is assembled and welded. The center-to-center distance of pin holes shall be correct within 1/32 inch (0.8 mm) for an individual component or member. The diameter of pin holes shall not exceed that of the pin by more than 1/50 inch (0.5 mm) for pins 4 inches (100 mm) or less in diameter, nor more than 1/32 inch (0.8 mm) for pins larger than 4 inches (100 mm) in diameter.

712.3.3.12 Casting. Castings shall be free from inclusions of foreign material, casting faults, injurious blow holes or other defects which render them unsuitable for the service intended. Castings shall be properly filleted at re-entrant angles. No tolerance will be allowed below the

dimensions shown on the plans for thicknesses over an appreciable area of the casting. A reasonable oversize will not be cause for rejection.

712.3.3.13 Bent plates shall be cold bent and so taken from the stock plates that the bend line will be at right angles to the direction of rolling. The radius of bends, measured to the concave face of the metal, shall be not less and preferably shall be greater than shown in the following table, in which "T" is the thickness of the plate:

Angle Through Which Plate is Bent	**Minimum Radius**
61 degrees to 90 degrees	1.0 T
Over 90 degrees to 120 degrees	1.5 T
Over 120 degrees to 150 degrees	2.0 T

712.3.3.13.1 If a shorter radius is required, the plates shall be hot bent. Hot bent plates shall also be bent at right angles to the direction of rolling. Before hot or cold bending, the corners of the plate shall be rounded to a radius of 1/16 inch (1.5 mm) throughout that portion of the plate at which the bending is to occur.

712.3.3.14 Surface Finish. Bearing plates of rolled steel not requiring a surface finish shall be straightened to a plane surface. The surfaces of plates of rolled steel or cast material which are to be in contact shall be finished as shown on the plans, and the final finish shall be made in a manner to give at least 50 percent contact as indicated by standard machinist's blue test. Rockers and pedestals made from rolled steel shall be finished after welding. If a flat surface is shown on the plans, the tolerance shall be 0.003 inch per inch (0.003 mm/mm) in any direction. Flat surfaces in full contact shall be finished at right angles to each other. Bearing plates shall be assembled in sets, and each set shall be matchmarked before inspection. The surface finish of bearing and base plates and other bearing surfaces that are to come in contact with each other or with concrete shall meet the following surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part I:

	Micro-inches (mm) Max.
Steel Slabs	2000 (51)
Heavy Plates in Contact in Shoes to be Welded	1000 (25)
Milled Ends of Compression Members, Stiffeners and Fillers	500 (12)
Bridge Rollers and Rockers	250 6)
Pins and Pin Holes	125 (3)
Sliding Bearings	125 (3)

712.3.3.15 Horizontally Curved Rolled Beams and Plate Girders. If the plans show rolled beams or welded plate girders to be finished to a horizontal curvature, they shall be fabricated as follows: Rolled beams shall be curved by the heat curving procedure. Welded plate girders may be fabricated by cutting the flanges to the specified curvature before they are attached to the webs or, if not prohibited by the contract, may be curved by the heat curving procedure.

712.3.3.15.1 If the heat curving procedure is used, it shall comply with the following requirements:

(a) Material. Heat curving of rolled beams and welded plate girders shall be limited to AASHTO M 270 Grade 36 (ASTM A 709 Grade 36), AASHTO M 270 Grade 50 (ASTM A 709 Grade 50) and AASHTO M 270 Grade 50W (ASTM A 709 Grade 50W).

(b) Type of Heating. Beams and girders may be curved by either continuous or V-type heating.

(1) For the continuous method, strips along the edge of the top and bottom flanges shall be heated simultaneously. The strips shall be of sufficient width and temperature to obtain the required curvature.

(2) For the V-type heating, the top and bottom flanges shall be heated in truncated triangular or wedge-shaped areas having their bases along the flange edge and spaced at regular intervals along each flange as required to obtain the specified curvature. Heating shall progress along the top and bottom flange at approximately the same rate. The apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached. If the radius of curvature is 1000 feet (300 m) or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. If the radius of curvature is less than 1000 feet (300 m), the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to 1/8 of the flange width or 3 inches (75 mm), whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches (250 mm). Variations in the pattern specified above may be made with the approval of the engineer.

(3) For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is mandatory only when the flange thickness is 1 1/4 inches (32 mm) or greater, in which case the two surfaces shall be heated concurrently. The maximum temperature shall be as specified in subparagraph (d).

(c) Control of Web and Flange Distortion. To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so that heat is not applied directly to the web. If excessive web or flange buckling is encountered, the procedure shall be modified immediately.

(d) Temperature. The heat curving operation shall be conducted under rigid controls so the temperature of the steel does not exceed 1100 F (593 C) as measured by temperature-indicating crayons or other suitable means applied before heating. The heating of the steel to a temperature greater than 1200 F (650 C) will be considered destructive heating and will be positive cause for rejection of the steel. Quenching with water or water and air, will not be permitted. Cooling with dry compressed air will be permitted after the steel has cooled to 600 F (315 C).

(e) Position for Heating. The girder may be heat curved with the web in either a vertical or a horizontal position. When curved in the vertical position, the girder shall be braced or supported in such a manner that the tendency of the girder to deflect laterally during the heat curving process will not cause the girder to overturn. When curved in the horizontal position, the girder shall be supported near its ends and at intermediate points, if required, to obtain a uniform curvature. When the girder is positioned horizontally for heating, intermediate safety catch blocks shall be maintained at the mid-length of the girder within 2 inches (50 mm) of the flanges at all times during the heating process.

(f) Sequence of Operations. Heat curving shall be completed before the girder is painted. The heat curving operation may be conducted either before or after all the required welding of transverse intermediate stiffeners is completed. However, unless provisions are made for girder shrinkage, connection plates and bearing stiffeners shall be located and attached after heat curving. If longitudinal stiffeners are required, they shall be heat curved or

oxygen-cut separately and then welded to the curved girder. If cover plates are to be attached to rolled beams, the beams shall be heat curved before the cover plates are attached. Cover plates shall be either heat curved or oxygen-cut separately and then welded to the curved beam.

712.3.3.16 Shop Assembly and Measurement.

712.3.3.16.1 Shop Assembly.

(a) If required by the contract, the structural steel for bridges shall be shop assembled for inspection in their entirety, supported only at points of bearing. Long bridges required to be shop assembled in their entirety may be divided into units for assembly with each unit extending from expansion device to expansion device.

(b) Beams and girders of all other bridges shall be assembled for inspection in line assemblies with a minimum length assembled of one complete span, from bearing to bearing.

(c) During shop assembly connecting parts shall be firmly fastened together and held in alignment with a minimum of four drift pins and four make-up bolts per flange splice plate, web splice plate or similar connecting part, until assembly inspection is complete.

712.3.3.16.2 Shop Measurement of Curvature and Camber. Horizontal curvature and vertical camber will not be measured for QA inspection in the shop until all welding, drilling and heat curving operations have been completed and the flanges have cooled to a uniform temperature. For bridges not requiring complete shop assembly, the vertical camber will be checked with the girder in a horizontal position, and the horizontal curvature will be checked with the girder in either a horizontal or vertical position. The shop drawings shall show the required off-sets for both curvature and camber at approximately 10-foot (3 m) intervals, measured along the girder. The permissible variation in specified sweep for horizontally curved beams and girders, measured in inches, but not to exceed 1/2 inch (13 mm), shall be as follows:

ENGLISH
1/8 inch x 0.1 x (number of feet from end bearing)

METRIC
3 mm x 0.1 x (number of meters from end bearing x 0.3)

The shop drawings shall show the required offsets for both curvature and camber at approximately 10-foot (3 m) intervals, measured along the girder.

712.3.4 Shear Connector Studs. Shear connector studs may be attached to the beams or girders either in the fabricating shop or in the field. If the shear connector studs are to be attached in the field, the contractor shall notify the engineer not less than one week before the contractor begins welding shear connectors to the beams or girders so the engineer may inspect for approval the proposed welding procedure and equipment. Only welding procedures, equipment and operators meeting the approval of the requirements of Sec 712 shall be used.

712.3.4.1 If necessary to obtain satisfactory welds, areas to which shear connectors are to be attached shall be cleaned of all foreign material such as oil, grease or paint. Cleaning may generally be done by use of wire brushes or other methods approved by the engineer. Where a shop coat of inorganic zinc primer has been applied, removal shall be limited to the minimum area necessary to apply the studs.

712.3.5 Shipping. Fabricated material shall not be shipped before a "Fabrication Inspection Shipment Release" is issued by the engineer. All parts shall be loaded and protected in a manner to prevent damage in transit. Loading and unloading of members shall be done with equipment adequate for the purpose. Pins, nuts, bolts and other small parts shall be boxed or crated. The "Fabrication Inspection Shipment Release" shall be delivered to the engineer at destination prior to erection of steel.

712.3.6 Handling, Transporting, Storing and Erecting. Fabricated material shall be properly braced and supported at all times to prevent damage from torsional, vertical and lateral deflections. Members suspected to have been damaged during handling, transporting, storing or erecting will be subjected to nondestructive tests as ordered by the engineer. The costs of these tests shall be borne by the contractor. Fabricated structural steel shall be stored on platforms, skids or other supports. Trough sections shall be stored in a manner to provide drainage. Long members shall be supported at frequent intervals. Girders and beams shall be handled and stored in an upright position. Any material which has become bent shall be straightened before being assembled or shall be replaced if necessary. Material intended for use in the finished structure shall not be used by the contractor for erection or temporary purposes unless such use is provided for in the contract or by written approval of the engineer.

712.4 Falsework. Staging and falsework necessary for the erection of the structure shall be furnished and placed and, upon completion of the erection, removed by the contractor. Adequate supports shall be placed at each splice point in the lower chords of truss spans except when erection is done by the cantilever method. If required, plans for falsework shall be submitted to the engineer before starting the work, but the engineer's acceptance of the plans will not relieve the contractor of the responsibility for obtaining satisfactory results.

712.5 Erection. Erection of all parts of the structure shall be in accordance with the erection diagram or working drawings. Surfaces to be in permanent contact shall have all burrs and loose scale removed. Before erection, machine finished surfaces shall be cleaned of the protective coating other than the primer permitted by Sec 712.2.7, and contact surfaces shall be given a heavy coat of graphite and oil. Reamed connections match-marked in the shop shall be erected in accordance with those match-marks. Interchange or reversal of reamed connections will not be allowed. Hammering which may damage or distort the members will not be permitted.

712.5.1 Truss spans, plate girders and continuous I-beams shall be supported to maintain required camber during erection. Fitting up bolts and drift pins shall be furnished by the contractor. High strength bolted field splices and primary connections, except for trusses and structures carrying live load erection stresses, shall have not less than one-half of the holes fitted with bolts and cylindrical drift pins using one-third fitting up bolts and two-thirds pins. Splices and primary connections carrying erection traffic during erection or truss connections, shall have not less than three-fourths of the holes filled with drift pins and bolts using one-third fitting up bolts and two-thirds pins. The specified ratio of pins to bolts shall apply to each element of the splice; for example, top flange, web and bottom flange of girders. Fitting up bolts shall be the same diameter as the high strength bolts. Drift pins shall be not less than 1/32 inch (0.8 mm) larger than the high strength bolts to provide a driving fit. Fitting up bolts shall be symmetrically placed so as to draw the splice pieces tight to such extent that a thin knife edge cannot be inserted between the pieces being connected. All fitting up bolts and drift pins shall be properly installed before starting to install high strength bolts. Bolts used for fitting up shall not be used in the final assembly. Holes which do not match shall be reamed only with the approval of the engineer. Drifting which would distort the metal will not be permitted.

712.5.2 The lead plates or preformed rubber and fabric pads shall be approximately 1/8 inch (3 mm) thick and 1/2 inch (13 mm) greater in length and width than bottom bearing plates

under which they are to be placed. Lead plates shall weigh (have a mass of) approximately 8 pounds per square foot (39 kg/m^2). Preformed rubber and fabric pads shall comply with the requirements of Sec 1038.3. Shop drawings are not required for lead plates or preformed rubber and fabric pads. Lead plates or preformed rubber and fabric pads are incidental to bearings and no direct payment will be made for furnishing or installing them.

712.6 Anchor Bolts. Anchor bolts for steel superstructures shall be set in the substructure units in accordance with the details shown on the plans. When anchor bolts are set during the placing of the concrete, they shall be accurately located and held firmly in a rigid template which spans the concrete with sufficient clearance to permit proper finishing of the surface of the concrete. The template shall remain in place until the concrete has set. Where permitted or required, the anchor bolt wells may be omitted and in lieu thereof, holes drilled into the substructure. The anchor bolt holes shall be drilled in the exact location shown, to the required depth, perpendicular to the plane of the bridge seat, and just prior to the time of setting the anchors. The drilled holes shall not be smaller than the diameter of the holes in the steel bearing plates or castings. When the anchor bolts are set in holes or wells, they shall be grouted in by using an expansive mortar meeting the requirements of Sec 1066. Excess mortar forced out of the holes shall be removed. The location of anchor bolts in relation to the center of slotted holes provided in movable plates and shoes shall be varied to compensate for movement of spans due to the temperature above or below 60 F (15 C). Nuts on anchor bolts through moving parts of expansion bearings shall be adjusted to provide ample clearance for free movement of the span.

712.7 Grouting. Grouting under bearing plates and castings to build them to the proper grade will not be permitted. Steel shims the full size of the plate of the bearing device may be used for this purpose. The shims shall be placed between the bottom of the stringers and the top of bearing plates if practicable. Shims shall be straightened to a plane surface.

712.8 Field Welding. All field welding shall be performed in accordance with the applicable requirements of Sec 712.3.3.7.

712.8.1 Falsework or Supporting Devices. Falsework or supporting devices designed to support the dead load of the beam or girder plus 100 percent shall be provided at each joint to be field welded. Falsework plans, including location of falsework bents or details of supporting and aligning devices or the contractor's alternate proposal for erection, shall be submitted to the engineer for review before shop drawings are submitted for approval. The engineer's review will not be considered as relieving the contractor of the responsibility to obtain acceptable welded joints. Field welded splices, properly aligned to produce joints acceptable to the engineer, may be welded on the ground. The contractor shall provide safe and adequate scaffolding, ladders and falsework.

712.8.2 Welding Procedures. Welding procedures, including pass sequences for field joints, shall be submitted to the engineer for review prior to submitting shop drawings. Weld passes shall be made symmetrically and shall alternate between both sides of the joint. The welding procedure shall indicate at what step in the welding sequence the contractor proposes to loosen or remove each alignment and support device.

712.9 Machine Bolts. Machine bolted field connections shall be made with machine bolts having American Standard Regular Heads and Nuts of hexagonal shape and shall conform to the requirements of ANSI B18.2.1 and B18.2.2. The threads shall extend slightly beyond the nut to permit burring. One plain washer meeting the requirements of ANSI B18.22.1 shall be used at all slotted holes.

712.10 High Strength Bolts.

712.10.1 Bolted Parts. The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed one in 20 with respect to a plane normal to the bolt axis. All bolted parts, including underhead bearing areas and joint surfaces within the grip of the bolt, shall fit solidly together when assembled in the snug tight condition and shall not be separated by gaskets or any other interposed compressible material. When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts or washers, shall be free of scale, dirt, burrs, other foreign material and other defects that would prevent solid seating of the parts. Contact surfaces within friction-type joints shall be free of oil, paint (except as provided in Sec 712.12.8), lacquer, rust inhibitor and galvanizing. All bolts, nuts and washers shall be free of rust, burrs, dirt, other foreign material and other defects that would prevent proper tensioning. All nuts for coated high strength bolts shall be properly lubricated with a visible water soluble lubricant. All nuts for uncoated high strength bolts shall be properly lubricated with a water soluble lubricant that is oily to the touch.

712.10.1.1 Snug Tightness of Connections. Regardless of the method of final tightening used to install the fasteners, the joint and all fasteners shall first be brought to the snug tight condition. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a person using an ordinary spud wrench. Snug tightening shall progress systematically from the most rigid part of the connection to the free edges. The bolts shall be retightened in a similar manner as necessary until all bolts are simultaneously snug tight and the section is fully compacted with the bolted parts of the joint in full contact.

712.10.2 Installation.

712.10.2.1 Bolt Tension. Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum bolt tension shown in Table I for the size and grade of fastener used. Threaded bolts shall be tightened by methods described in Sec 712.10.2.3, 712.10.2.4 or 712.10.2.5. If required because of bolt entering and wrench operation clearances, tightening may be done by turning the bolt while the nut is prevented from rotating. On non-parallel abutting surfaces where bevel washers are not required, the nut shall be torqued against the non-sloping surface. Nuts shall be placed on the inside face of exterior girders, the top of girder flanges or in other situations the least exposed position, except if inaccessible for turning, on a sloping surface or otherwise approved by the engineer. Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately 10 seconds. Bolts or nuts, once tensioned and subsequently loosened (turned), shall not be used as permanent bolts or nuts. Bolt tension calibration devices shall be calibrated and certified as to accuracy by a private testing lab within one year before usage or at any time the accuracy is questionable.

TABLE I
Bolt Tension and Projection
ENGLISH

Bolt Size (in.)	Minimum Bolt Tension (lb x 1000)		Maximum Bolt Projection (in.)
	A-325	A-490	
1/2	12	15	1/4
5/8	19	24	3/8
3/4	28	35	3/8
7/8	39	49	3/8
1	51	64	1/2
1 1/8	56	80	1/2
1 1/4	71	102	1/2
1 3/8	85	121	1/2
1 1/2	103	148	1/2

METRIC			
Bolt Size (mm)	**Minimum Bolt Tension (kN)**		**Maximum Bolt Projection (mm)**
	A-325M	A-490M	
M16 x 2	91	114	10
M20 x 2.5	142	179	10
M22 x 2.5	176	221	10
M24 x 3	205	257	13
M27 x 3	267	334	13
M30 x 3	326	408	13
M36 x 4	475	595	13

712.10.2.2 Washers. All fasteners shall have a hardened washer under the nut or bolt head, whichever is turned in tightening. All fasteners over all oversized or slotted holes shall also have a hardened washer under the non-turned element. Where an outer face of the bolted parts has a slope of more than one in 20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

712.10.2.3 Calibrated Wrench Method. When calibrated wrenches are used to provide the bolt tension specified in Table I, their setting shall be such as to induce a bolt tension 5 percent to 10 percent in excess of the specified value. These wrenches shall be calibrated at least once each working day by tightening in a device capable of indicating actual bolt tension not less than three typical bolts of each diameter from the bolts to be installed. Power wrenches shall be adjusted to stall or cut out at the selected tension. If manual torque wrenches are used, the torque indication corresponding to the selected tension shall be noted and used in the installation of all bolts of the tested lot. Nuts shall be in tightening motion when torque is measured. After the joint has been brought to a snug tight condition, all bolts in the joint shall be tightened by progressing systematically from the most rigid part of the joint to its free edges. When using calibrated wrenches to install several bolts in a single joint, the wrench shall be returned to "touch up" bolts previously tightened, which may have been loosened by the tightening of subsequent bolts, until all are tightened to the selected tension. During tightening, there shall be no rotation of the part not turned by the wrench.

712.10.2.4 Turn-of-Nut Method. When the turn-of-nut method is used to provide the bolt tension, there shall first be enough bolts brought to a snug tight condition as defined in Sec 712.10.1.1 to ensure that the parts of the joint are brought into full contact with each other. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable nut rotation specified in Table II with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.

TABLE II			
Nut[a] Rotation from Snug Tight Condition			
Disposition of Outer Faces of Bolted Parts			
Bolt length measured from underside of head to extreme end of point	Bolt faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters	2/3 turn	5/6 turn	1 turn

[a] Nut rotation is relative to bolts, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance shall be plus or minus 30 degrees; for bolts installed by 2/3 turn and more, the tolerance shall be plus or minus 45 degrees.

712.10.2.5 Load Indicating Bolt Method. Tightening by this method is permitted provided it can be demonstrated by the following procedure that the bolt has been tightened to not less than the bolt tension indicated in Table I. Three bolts of a representative length, and of the same grade, diameter and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the part turned in tightening each bolt. Each bolt specified shall be tightened in the calibration device until the spline drive has sheared off. When this method is used to provide the bolt tension, all bolts in the joint shall be tightened in stages to prevent or minimize slackening of the installed bolts. The first stage is to tighten all bolts to a snug tight condition at which point all of the faying surfaces of the joint should be firmly in contact. The final stage of tightening to full tension shall be accomplished by progressing systematically from the most rigid part of the joint to its free edges.

712.10.2.6 Bolt Length. When snug tight, the beginning of the bolt threads shall be even with or project slightly beyond the nut. When properly tensioned, the bolt projection shall not exceed the maximum as specified in Table I.

712.10.2.7 A Skidmore-Wilhelm Calibrator or an acceptable equivalent tension measuring device shall be required at each job site during erection. Periodic testing, at least once each working day when the calibrated wrench method is used, shall be performed to assure compliance with the installation test procedures required for the tightening method used, and to perform pre-installation job site rotational- capacity testing. Bolts too short for the Skidmore-Wilhelm Calibrator may be tested using direct tension indicators (DTI). The DTI shall be calibrated in the Skidmore-Wilhelm Calibrator using longer bolts.

712.10.2.8 The rotational-capacity test shall be performed on each rotational-capacity lot prior to the start of bolt installation. Hardened steel washers shall be part of the test regardless if they are not required as part of the installation procedure.

712.10.2.9 Weathered or rusted bolts or nuts not in accordance with Secs 712.10.2.7 and 712.10.2.8 shall be cleaned and relubricated prior to installation. Recleaned or relubricated bolt, nut and washer assemblies shall be retested in accordance with Sec 712.10.2.8 prior to installation.

712.10.2.10 Bolt, nut and washer (when required) combinations as installed shall be only from the established and tested rotational-capacity lot.

712.10.2.11 Calibrated wrench tightening shall be verified during actual installation in the assembled steel work. The wrench adjustment selected by the calibration shall not produce a bolt or nut rotation from snug tight greater than allowed in Sec 712.10.2.4 Table II.

712.10.3 Inspection. The engineer will observe the installation and tightening of bolt assemblies to determine that the selected tightening procedure is properly used and will determine that all bolt assemblies are tightened. The following verification inspection will be used:

(a) Either the engineer or the contractor in the presence of the engineer, shall use an inspecting torque wrench and bolt tension calibration device furnished by the contractor. Bolt tension calibration devices shall be calibrated and certified as to accuracy by a private testing lab within one year before usage or at any time the accuracy is questionable.

(b) Five bolt assemblies of a representative length, and of the same grade, diameter and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension. There shall be a washer under the part turned in tightening each bolt. Each bolt specified shall be tightened in the device by any convenient means to the minimum tension specified in Table I. The inspecting torque wrench then shall be applied to the tightened bolt and the torque necessary to turn the nut or head 5 degrees, approximately one inch (25 mm) at 12-inch (300 mm) radius, in the tightening direction shall be determined. Of the five values obtained, the highest and the lowest values shall be disregarded, with the average of the remaining three being taken as the job inspecting torque to be used in the manner specified in Sec 712.10.3(c). The inspecting torque shall be a re-established at intervals of not more than 30 calendar days or at any time appreciable changes are encountered.

(c) Bolts represented by the sample prescribed in Sec 712.10.3(b) which have been tightened in the structure will be inspected by applying, in the tightening direction, the inspecting wrench and its job inspecting torque to 10 percent of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of the job inspecting torque, the connection will be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection, and all bolts whose nut or head is turned by the job inspecting torque shall be tightened and re-inspected or the contractor, at the contractor's option, may re-tighten all of the bolts in the connection and then resubmit the connection for inspection.

712.11 Blank.

712.12 Protective Coating of Structural Steel.

712.12.1 Description. This work shall consist of the preparation of previously uncoated structural steel surfaces, furnishing and applying specified coatings, protection and drying of coatings, furnishing protection from coating spatter and disfigurement, and final cleanup.

712.12.2 Surface Preparation.

712.12.2.1 Oil, grease and other contaminants shall be removed with an approved solvent prior to blast cleaning. Where high strength bolts are installed prior to blast cleaning or finish coat, the lubricant on high strength bolt assemblies shall be removed with an approved solvent. Surfaces to be prime coated shall be blast cleaned with abrasives producing a height of profile

1.5 mils (38 µm) minimum and 3.0 mils (76 µm) maximum for all systems. The blast cleaned surfaces shall be completely free of all oil, grease, dirt, rust, mill scale, weld spatter and other foreign matter, except that very light shadows, streaks or slight discolorations caused by rust stain or mill scale oxides may remain. At least 95 percent of each square inch (92 square millimeters) of surface area shall be free of all visible residues, and the remainder shall be limited to the discoloration mentioned above. Surfaces shall be cleaned to a condition equal to or better than the appearance of the pictorial surface preparation standard, labeled Sa 2 1/2 in ASTM D 2200, that applies to the starting rust grade of the steel. Surfaces cleaned to meet Steel Structures Painting Council Specification SSPC-SP-10 will meet these requirements.

712.12.2.2 After blast cleaning, the surfaces shall be brushed with clean brushes, blown off with compressed air or cleaned by vacuum to remove any trace of blast products, dust or dirt from the surface, and also from all pockets and corners. Compressors shall be equipped with moisture and oil separators, traps and filters to maintain a clean, dry, oil free air supply at the end of the hose. Separators and traps shall be of adequate size and shall be drained periodically during operations. Filters shall be checked and replaced when necessary. The blast cleaned surfaces shall be given the specified prime coat as soon as practicable, but in any case within 24 hours after blast cleaning. If blast cleaned surfaces rust before coating is accomplished, they shall be reblasted by the contractor at the contractor's expense. All rusted, damaged or uncoated areas, including ungalvanized nuts, bolts and washers to be prime coated in the field, shall be blast cleaned to the same degree as specified above for the applicable coating system. Care shall be exercised to ensure the blasted steel remains free of grease and oil during handling.

712.12.2.3 When there is contamination of any surface to be coated, all dirt, oil, grease, oxidation products and other detrimental foreign matter shall be removed to the satisfaction of the engineer. If these contaminants cannot be removed by other methods, the contractor shall remove all oil and grease by scrubbing with an approved solvent, blast cleaning the rejected areas of all previously applied coatings and recoating in accordance with these specifications.

712.12.3 Systems of Coatings. The required system and color or choice of systems and color will be specified on the plans. Each coat of the specified system shall be applied to all structural steel, unless the contract specifically delineates otherwise. The system and color of coating to be shop-applied shall be shown on the shop drawings. All coatings shall comply with local VOC (Volatile Organic Compound) regulations where the paint is applied. The system and color shall not vary for any portion of the entire structure, including material for field repairs, and shall be compatible products of a single manufacturer. The contractor shall coordinate the various items of work to assure compliance with the requirements of this section. All structural steel shall be coated with one of the following systems:

System F (High Solids, Inorganic Zinc Silicate)		
Coating	**Specification**	**Dry Film Thickness mils (µm)**
Prime Coat	Sec 1045.5	3.0 (75) min.-6 (150) max.
System G (High Solids, Inorganic Zinc Silicate-Epoxy-Polyurethane)		
Coating	**Specification**	**Dry Film Thickness mils (µm)**
Prime Coat	Sec 1045.5	3.0 (75) min.-6 (150) max.
Epoxy Intermediate Coat	Sec 1045.6	3.0 (75) min.-5 (125) max.
Polyurethane Finish Coat, Gray or Brown	Sec 1045.7	2.0 (50) min.-4 (100) max.
System H (High Solids, Inorganic Zinc Silicate-Waterborne Acrylic Intermediate-Waterborne Acrylic Finish)		
Coating	**Specification**	**Dry Film Thickness mils (µm)**
Prime Coat	Sec 1045.5	3.0 (75) min.-6 (150) max.
Waterborne Acrylic, Intermediate Coat	Sec 1045.8	2.0 (50) min.-4 (100) max.
Waterborne Acrylic, Finish Coat, Gray or Brown	Sec 1045.8	2.0 (50) min.-4 (100) max.

712.12.3.1 Unless otherwise indicated on the plans, the application of the intermediate and finish coats for Systems G and H shall be field applied over the prime coat on the structure within the following limits:

(a) The field coating for beam and girder span structures shall include the facia girders or beams. The limits of the facia girders or beams shall include the bottom of the top exterior flanges, top of bottom exterior flanges, the exterior web area, the exterior face of the bottom flange and the bottom of the bottom flange. Areas of steel to be in contact with concrete shall not receive the intermediate and finish coats. The field coating shall also be applied to the exterior bearings, except where bearings will be encased in concrete.

(b) The surfaces of all structural steel located under expansion joints of beam and girder span structures shall be field coated for a distance of 1-1/2 times the girder depth, but not less than 10 feet (3 m), from the centerline of the joint. Within this limit, the items to be field coated shall include all surfaces of beams, girders, bearings, diaphragms, stiffeners and miscellaneous structural steel items. Areas of steel to be in contact with concrete shall not receive the intermediate and finish coats. The limits of the field coating shall be masked to provide crisp, straight lines and to prevent overspray on adjacent areas.

(c) For structure types other than beam and girder structures, including trusses, the above limits shall not apply and all structural steel for the entire structure shall be field coated, except the areas of steel to be in contact with concrete.

712.12.3.2 The dry film thickness of the coatings will be measured by magnetic type gauges in accordance with MoDOT Test Method T45. At the option of the engineer, the adhesion of the prime coat will be measured in accordance with ASTM D 3359, Test Method A. When the adhesion is tested, each test result shall equal or exceed scale 3A. Locations for adhesion tests will be randomly selected. Test locations shall be in areas of least visibility in the completed structure and shall be touched up in an approved manner after completion of the

test. When satisfactory test results are not obtained, additional adhesion tests shall be taken to determine the area of insufficient adhesion. For these areas, the surface shall be prepared in accordance with Sec 712.12.2.1 and the area recoated in accordance with these specifications.

712.12.3.2.1 If additional prime coat is required to provide the specified minimum thickness, it shall be applied as soon as possible but within 24 hours of the initial application.

712.12.3.3 Coating Material Storage. All coating material shall be stored in a manner which will protect them from the effects of the elements, away from direct sunlight. Exposure to storage temperatures outside the range recommended in the coating manufacturer's written specifications will be cause for rejection of the material. For those material for which the manufacturer has established a shelf life, each container shall be stamped by the manufacturer with an expiration date after which the material shall not be used.

712.12.4 Weather Conditions.

712.12.4.1 The prime coat shall not be applied when the temperature of the air is less than 34 F (1 C) or greater than 110 F (43 C), nor when the temperature of the metal is less than 34 F (1 C) or greater than 130 F (54 C). The prime coat shall not be applied when the relative humidity is less than 30 percent or greater than 90 percent. Finish and intermediate coats applied over the prime coat shall be applied in accordance with the manufacturer's written specifications, which shall be furnished to the engineer.

712.12.4.1.1 The minimums and maximums or additional requirements established by the coating manufacturer's written specifications for recommended air or metal temperature or relative humidity shall apply if they are more restrictive than those specified herein.

712.12.4.2 Coatings shall not be applied in rain, snow, fog or mist or when the steel surface temperature is at or below 5 F (-15 C) above the dew point. The dew point will be determined in accordance with MoDOT Test Method T38. Coatings shall not be applied to wet, damp, frosted or ice-coated surfaces.

712.12.4.3 When coatings are applied in a protected area to eliminate the above conditions, the coated steel shall remain in the protected area until the coatings are cured.

712.12.4.4 Any uncured coatings exposed to freezing, excess humidity, rain, snow, condensation or curing temperatures outside the range recommended by the manufacturer shall be considered damaged. Damaged coatings shall be permitted to dry, then be removed and the surface blast cleaned and recoated.

712.12.5 Thinning. Thinners are permitted as recommended by the manufacturer's written specifications, provided VOC limits are not exceeded.

712.12.6 Tinting. If successive coats of the same color and the minimum thickness for each successive coat are specified, alternate coats shall be sufficiently tinted to produce enough contrast in wet film to indicate complete surface coverage. If the first coat is to be approximately the color of the cleaned steel, the coating material shall be tinted. Tinting material shall be compatible with the coating and not detrimental to its service life. Tinting is not required between successive prime coats, provided enough contrast exists in wet film to indicate complete coverage.

712.12.6.1 For partial application of intermediate and finish coats for Systems G and H as outlined in Sec 712.12.3.1, the tint of the prime coat shall be similar to the color of the field coat to be used.

712.12.7 Application. Coatings shall be applied by brushing, air spraying, airless spraying, rolling or a combination of these methods as required to meet all specified requirements and for a uniform application free from runs, sags and holidays. Daubers or sheepskins shall be used when no other method is practicable for proper application in places of difficult access. The manufacturer's written specifications for application shall be submitted to the engineer for review. Coatings shall be applied in accordance with the manufacturer's written specifications, but shall be compatible with the following requirements:

(a) After initial mixing, primer shall be strained through a screen not coarser than 30 (600 µm) mesh nor finer than 60 (250 µm) mesh.

(b) Unused primer may be mixed and used within eight hours following initial mixing so long as the pigment can be easily redispersed, unless indicated otherwise by the manufacturer's written specifications. For material where the manufacturer has established a pot life after mixing, the primer shall be applied in the specified time or be discarded.

(c) If deficiencies in the quality of work or material result in rejection, the contractor shall blast clean the entire rejected areas of all previously applied coatings and recoat in accordance with requirements of these specifications, unless otherwise approved by the engineer.

(d) After the initial mixing and until application of primer, the mixture shall be kept under constant agitation.

712.12.7.1 Spray Application. The equipment used shall be capable of properly atomizing the coating to be applied and shall be equipped with suitable pressure regulators and gauges. Spray equipment shall be kept sufficiently clean so that dirt, dried coating material and other foreign material are not deposited in the coating film. Traps, separators or filters shall be provided to prevent oil, water and other foreign material from being deposited in the coating film. Traps and separators shall be drained periodically, and filters shall be replaced periodically. Any solvents left in the equipment shall be completely removed before application. Ingredients shall be kept properly mixed during coating application by continuous mechanical agitation in the spray pots or containers. When coatings are spray-applied, all runs and sags shall be brushed out immediately. Blind sides of bolts and other areas inaccessible to the spray gun shall be coated by brush, daubers or sheepskins prior to spray application.

712.12.7.2 Brush Application. Brushes shall be of a style and quality that will enable proper application of the coating. Flat brushes shall not exceed 5 inches (125 mm) in width. Coatings shall be worked into all crevices and corners. Surfaces not accessible to brushes shall be coated by spray, daubers or sheepskins. All runs or sags shall be brushed out immediately.

712.12.7.3 Roller Application. Rollers shall be of a style and quality that will enable proper application of the coating and all runs or sags shall be brushed out immediately. The roller nap shall be such as to leave a smooth surface. Surfaces not accessible to rollers, including crevices and corners, shall be coated by spray, brushes, daubers or sheepskins.

712.12.7.4 Curing of Coatings. Curing time for recoating shall be within the limits of the manufacturer's written specifications except as modified by Sec 712.12.3.2.1 for successive applications of prime coat. Application of the finish coat over the intermediate coat shall be accomplished within the recoat time for proper adhesion established by the manufacturer's written specifications. Regardless of manufacturer's specifications, the finish coat shall be applied within seven days after application of intermediate coats.

712.12.8 Shop Coating. All surfaces of fabricated structural steel, including areas which will be inaccessible after assembly, contact surfaces of high strength bolted connections, and all surfaces to be in contact with concrete in the completed structure shall be coated in the shop with the prime coat. The primer shall be of the type and thickness specified, except as modified by Secs 712.12.8.1 and 712.12.8.2. Structural steel sway bracing for substructure may be prepared and coated in the field.

712.12.8.1 Contact surfaces of high strength bolted connections shall be prime coated to produce a dry film thickness of not less than 1.5 mils (40 µm) nor more than 2.5 mils (65 µm). The maximum limit of 2.5 mils (65 µm) may be increased provided acceptable test results in accordance with the Testing Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints (AISC "Specification for Structural Joints Using ASTM A 325 or A 490 Bolts", Appendix A) are submitted and approved by the engineer. The tests shall meet the requirements for the slip coefficient and creep resistance for Class B coatings and shall be performed by a nationally recognized independent testing laboratory. Any change in the formulation of the coating will require retesting, except when thinned within the limits of manufacturer's written specifications. At the contractor's option, the contact surfaces of connections for all non-slab bearing diaphragms on non-curved girders shall be prime coated with a dry film thickness of not less than 3.0 mils (75 µm) nor more than 6.0 mils (150 µm), unless noted otherwise on the design plans. Contact surfaces of high strength bolted connections shall be protected from contamination by the intermediate and finish coats.

712.12.8.2 Surfaces which will not be in contact, but which will be inaccessible after assembly, shall be prime coated to produce a dry film thickness of not less than 3.0 mils (75 µm) nor more than 6.0 mils (150 µm). Dry film thickness on surfaces which will be in contact with concrete may be reduced to 2.0 mils (50 µm) provided thorough and complete coverage is obtained. Although shear connectors need not be coated when a field coat will be applied, it is not necessary to protect them from overspray when coating other parts of the beam or girder. Where a field coat will not be applied to the entire structure, the shear connectors shall be coated to ensure complete coverage. Coating thickness measurements will not be made on shear connections.

712.12.8.3 The inside surfaces of bolt holes shall be coated to ensure complete coverage, unless a field coat will be applied to the entire structure. Coating thickness measurements will not be made.

712.12.8.3.1 The galvanized coating of nuts, bolts and washers damaged during shop installation shall be shop repaired in accordance with Secs 712.12.9.1 and 712.12.9.1.1.

712.12.8.4 No coatings shall be applied before shop inspection of fabrication has been completed. Surfaces of steel within 2 inches (50 mm) of edges to be field welded shall not be coated in the shop.

712.12.8.5 For areas where a field coat will be applied, erection marks and match marks shall be painted upon surface areas after application of the shop coat in locations as approved by the engineer. Material shall not be loaded for shipment until the coating has cured.

712.12.8.5.1 For areas where a field coat will not be applied, erection and match marks shall be located in areas of least visibility in the completed structure. Where it is impossible to locate erection and match marks in low visibility areas, the marks shall be touched up in the field.

712.12.9 Field Coating. Intermediate and finish coats for the specified coating system shall be applied in the field. The contractor shall also be responsible for final cleanup and field touch-up of any shop applied coating, including surface preparation and coating of field

connections, welds or bolts, areas masked in the shop and all damaged or defective coating and rusted areas. Surface preparation for field touch-up shall be performed as specified in Sec 712.12.2 unless otherwise approved by the engineer. The touch-up field coat shall be made with the same coating used for the shop applied coat. Damage to the coating of galvanized bolts, nuts and washers where bare steel is exposed shall be repaired in accordance with these specifications or, at the option of the contractor, the connection can be prepared as specified in Sec 712.12.2 followed by a touch-up field coat application of the required coating system.

712.12.9.1 The galvanized coating of nuts, bolts and washers damaged during installation shall be repaired. Lubricants shall be removed by solvent cleaning, removal of rust using hand tool cleaning in accordance with SSPC-SP-2 or power tool cleaning in accordance with SSPC-SP-3 and application of an approved aluminum epoxy mastic or an organic zinc-rich epoxy. The touch-up material shall be compatible with and from the same manufacturer as the coating system to be used for the structure. Prior to field coating operations, the contractor shall submit information on the specific products to be used, including compatibility data and applicable recoating times to the engineer for review. Subsequent coatings shall be applied within the recoat time recommended by the manufacturer.

712.12.9.1.1 For areas of the structure that will not receive a field coat, the color of the touch-up material for bolts specified in Sec 712.12.9.1 shall be similar to galvanized metal.

712.12.9.1.2 If repairs to the galvanized coating of shop-installed nuts, bolts and washers have previously been performed in accordance with Sec 712.12.8.3.1 or if epoxy mastics are otherwise shop-applied to structural steel, the contractor shall be responsible for any special field preparation required for proper adhesion of subsequent field coats to the epoxy coating. Prior to field coating operations, the contractor shall submit manufacturer's recommendations to the engineer.

712.12.9.1.3 Previously coated or adjacent areas shall be masked or otherwise protected from material used to touch-up the galvanized coating of fasteners.

712.12.9.2 Field coatings, except for touch-up and coating of inaccessible surfaces, shall not be applied until the concrete deck has been placed, the forms removed, and all concrete spatter and all foreign material and contaminants are removed from existing coatings. The sequence of work shall be arranged to provide ample time for each coat to cure before the next coat is applied. In no case shall a coat be applied until the previous coat has been approved by the engineer. Excessive rust streaks or coatings on concrete masonry shall be removed by sandblasting or by other approved methods, without damage to the masonry.

712.12.9.3 Work Under Stage Construction Contracts. If complete field coating is not included in the contract for erection of structural steel, the touch-up coating of newly erected work and the coating of surfaces which will be inaccessible after erection shall be included as part of the work to be performed under the contract for erection. Field coating under any contract that does not include the erection shall include cleaning, preparation of any previously applied coatings, repairs and spot application of coatings required at the time the work is performed.

712.12.9.3.1 Prior to field coating of structural steel which was erected under a previous contract, the contractor shall submit manufacturer's recommendations to the engineer which shall outline requirements for cleaning and preparation of all existing coatings. These shall include requirements for preparation of organic epoxies or epoxy mastics previously applied for touch-up or other purposes.

712.12.9.4 If partial application of the field finish coats to a structure as outlined in Sec 712.12.3.1 is required or permitted, the contractor shall be responsible for field touch-up

coating to areas of the structural steel outside the limits to receive the intermediate and finish coats. Touch-up shall be as specified in Sec 712.12.9, and no direct payment will be made.

712.12.10 Identification. The contractor shall, at the completion of the coating application, stencil in black paint on the structure the number of the bridge, the word "COATED", the system used and the month and year the coating was completed. The letters shall be capitals approximately 3 inches (75 mm) high. The legend shall be stenciled on the outside face of an outside stringer or girder near each end of the bridge as specified by the engineer.

712.12.11 Property and Traffic Protection. The contractor shall protect pedestrian, vehicular, railroad and other traffic, persons and property, upon, beneath and in the vicinity of the structure, and all portions of the bridge against damage or disfigurement by blast media, blast residue, coatings, coating material, equipment or by any other operations.

712.13 Recoating of Structural Steel.

712.13.1 Description. This work shall consist of field preparation of structural steel surfaces to be recoated, furnishing and applying specified coatings, protection and drying of coatings, furnishing protection from coating spatter and disfigurement and final cleanup.

712.13.2 Systems of Protective Coatings. All structural steel shall be recoated by the contractor in the field using one of the complete systems, including prime coats, as specified in Sec 712.12.3, unless noted otherwise. Recoating of structural steel including surface preparation, weather conditions, application, touch-up and protection shall be in accordance with all requirements of Sec 712.12.

712.13.3 Surface Preparation. Surface preparation shall be in accordance with Sec 712.12.2. Oil, grease and other contaminants shall be removed with an approved solvent prior to blast cleaning. All existing coatings and paint shall be removed by blast cleaning unless specifically indicated otherwise in the contract.

712.13.4 All seams and joints which cannot be satisfactorily sealed or coated shall be adequately caulked with compounds compatible with the coating system being applied. Caulking material shall comply with the coating manufacturer's recommendations and meet the approval of the engineer. Caulking shall be satisfactorily completed for an entire joint or seam after application of the prime coat and before application of any specified finish or intermediate coats.

712.13.5 Identification. The contractor shall, at the completion of recoating, stencil in black paint on the structure the number of the bridge, the word "RECOATED", the system used and the month and year the coating was completed. The letters shall be capitals approximately 3 inches (75 mm) high. The legend shall be stenciled on the outside face of an outside stringer or girder near each end of the bridge as specified by the engineer.

712.14 Galvanized Metal. Galvanizing shall be done after fabrication. Galvanized material on which the galvanizing has been damaged will be rejected or may, with approval of the engineer, be repaired in the field by the zinc alloy stick method. Required field welds and adjacent areas on which galvanizing has been damaged shall be galvanized by this same method. The zinc alloy stick shall be cast from zinc, tin and lead in combination with fluxing ingredients. The compound shall be completely liquid at a temperature not lower than 475 F (246 C). The area to be regalvanized shall be thoroughly cleaned, including the removal of slag on welds. The surface shall be heated with a torch to approximately 600 F (315 C), and the alloy stick rubbed over the surface to fix a deposit. While the alloy is still liquid, a clean wire brush shall be used to smooth the deposit evenly over the entire area being regalvanized. If a heavy deposit or build-up is required to match the original coating, more alloy shall be

added immediately to the initial bond deposit and spread with a paddle or brush until the required thickness is obtained.

712.15 Steel Bar Dams. Steel bar dams placed at expansion devices on existing bridges to serve as headers for surfacing material shall be installed in a manner that will not interfere with the movement of the expansion devices.

712.16 Method of Measurement.

712.16.1 Payment for structural steel and wrought iron weights (masses) will be based on plan quantities. The theoretical weight (mass) of the various sections will be used to compute the plan quantities of the material incorporated in the completed structure. No allowance will be made for overrun in scale weights (masses) or for erection bolts, excess field bolts or similar items, or the weight (mass) of any coating, galvanizing or weld material.

712.16.2 The weight (mass) of steel bolts for steel to steel connections will be included in the plan quantities for fabricated structural steel on the basis of following weights (masses) per 100 bolts:

ENGLISH	
Bolt Size (in.)	**Weight (lb)**
5/8	40
¾	65
7/8	95
1	135
METRIC	
Bolt Size (mm)	**Mass (kg)**
M16	15
M20	30
M22	43
M24	55
M27	75
M30	100

These specified weights (masses) will be considered to cover the head, nut, any required washers and only that part of the bolt extending outside the grip of steel.

712.16.3 The weight (mass) of bolts connecting steel to concrete or steel to timber will be included for payment as fabricated structural steel and the full weight of the bolts will be computed.

712.16.4 Bolts for attaching timber members to any part of a structure will be classified as hardware and no direct payment will be made.

712.16.5 Castings will be computed on the basis of the theoretical weight (mass) of the material in the completed structure, and no allowance will be made for overrun in scale weights (masses) or for the weight (mass) of any coating material, galvanizing material or other protective coatings.

712.16.6 Weights (Masses) of structural steel, wrought iron and castings will be computed to the nearest 10 pounds (5 kg) of the total weight (mass) of each class of material in the completed structure.

712.16.7 If coating of steel structures is specified as a contract item, the method of payment will be included in the contract.

712.16.7.1 If the contract specifies a unit of measurement of coating steel structures in tons (megagrams), the weight (mass) of the steel to be cleaned and coated will be based on plan quantities to the nearest 1/10 ton (0.1 Mg). The weight (mass) will not vary with the number of coats applied.

712.16.7.2 If the contract specifies a unit of measurement of coating steel structures in square feet (square meters), the area will be computed to the nearest 100 square feet (10 m^2) of structural steel to be field coated. The area computations are approximate and do not include diaphragms, stiffeners and all other miscellaneous steel within the limits of the field coatings. The area will not vary with the number of coats applied. Final measurement will not be made.

712.16.8 If recoating of steel structures is specified as a contract item, the method of measurement will be included in the contract. The contract will indicate the estimated number of tons (megagrams) to be coated for informational purposes.

712.16.8.1 Measurement will not be made when the contract specifies units of measurement per lump sum.

712.16.8.2 If the contract specifies a unit of measurement of surface preparation or recoating steel structures in square feet (square meters), the area will be computed to the nearest 100 square feet (10 m^2) of girders to be recoated. The area computations are approximate and do not include bearings, diaphragms, stiffeners and all other miscellaneous steel within the limits of the field coating. The area will not vary with the number of coats applied. Final measurement will not be made.

712.16.9 A steel bar dam consists of the complete assembly on both sides of the expansion joint and will be considered a unit.

712.16.10 The weight (mass) of shear connectors will be based on the theoretical weight (mass) and will be included for payment in the weight (mass) of material to which the connectors are attached.

712.17 Basis of Payment.

712.17.1 Payment for fabricated structural steel, fabricated wrought iron, steel castings and gray iron castings will be based on the plan quantities. Any change in the plan quantities based on approved change orders will be paid for at the contract unit price. Payment for the shop prime coat including inaccessible areas shall be included in the cost of fabricated structural steel, otherwise no direct payment will be made. No direct payment will be made for coating of bolted field connections, touch-up, galvanizing, applying protective coating to machined surfaces or for cleaning coatings and rust streaks from finished concrete.

712.17.2 If specified as a contract item, the accepted quantity of coating structural steel will be paid for at the contract unit price for coating, except that the cost of shop applied coats shall be included in the cost of the fabricated structural steel, otherwise no direct payment will be made. No direct payment will be made for stencils, paint and painting specified in Sec 712.12.10. No direct payment will be made for field touch-up specified in Sec 712.12.9.

712.17.3 The accepted quantity of recoating will be paid for at the contract unit price for recoating each bridge specified in the contract. No direct payment will be made for stencils,

paint and painting specified in Sec 712.13.5. No direct payment will be made for field touch-up specified in Sec 712.12.9.

712.17.4 The accepted number of steel bar dams will be paid for at the contract unit price.