NEW YORK STATE

STEEL CONSTRUCTION MANUAL

DEPARTMENT OF TRANSPORTATION
DESIGN AND CONSTRUCTION DIVISION

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NEW YORK STATE
STEEL CONSTRUCTION
MANUAL

STATE OF NEW YORK
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DEPARTMENT OF TRANSPORTATION
RAYMOND T. SCHULER — COMMISSIONER
FOREWORD

The New York State Steel Construction Manual is a part of the Contract Documents for the Department of Transportation construction projects. The Manual is a mandatory supplement to the Section 616—Structural Steel and Section 715, Subsection 715.01—Structural Steel, of the Standard Specifications.

The Manual has been prepared to define minimum requirements for shop drawings, fabrication, and erection of structural steel including necessary inspection and nondestructive testing. In order to incorporate all essential requirements in a single volume, the Manual contains all pertinent provisions of the Structural Welding Code of the American Welding Society (AWS D1.1-72) which have been adopted by the State, as well as other provisions of the code which have been modified to reflect specific requirements of New York State and the Federal Highway Administration.
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SECTION I

DRAWINGS

101. CONTRACT DRAWINGS.

101.1. Definition: The drawings which are a part of the Contract Documents, hereinafter designated as the "Contract Drawings," "Contract Plans," or "Plans," are all Contract Drawings under the provisions of the Contract Documents and are not intended to be "Shop Drawings."

101.2. Details: Any details not sufficiently shown on the Contract Drawings will be furnished to the Contractor by the Deputy Chief Engineer (Structures) (D.C.F.S.) upon request.

101.3. Dimensions: In case of a difference on any Contract Drawing between scale dimensions and figures, the figures shall be followed.

101.4. Errors: The Contractor shall verify and be responsible for the correctness of all dimensions other than the principal controlling dimensions shown on the Contract Drawings, and shall call the attention of the D.C.F.S. to any errors or discrepancies that he may discover therein. The Contractor shall have no claim for damages that may result from following an error except for an error in the principal controlling dimensions and material properties shown on the Contract Drawings.

101.5. Principal Controlling Dimensions and Material Properties: The following shall be considered principal controlling dimensions and material properties:

(a) Length of span (horizontal distance between bearing or pin centerlines).
(b) Length of member - out to out.
(c) Thickness, width and length of all plates.
(d) Dimensions, weight per foot and length of shapes.
(e) Diameter of high-strength bolts and rivets.
(f) All dimensions of machined pins, hangers and bearing devices.
(g) Camber and horizontal curvature of members.
(h) Elevation of pedestals, bridge seats and other supports for structural steel.
(i) Type and grade of metal.
(j) Size of welds.

The Contractor shall be responsible for modifying dimensions of members and pieces to compensate for weld shrinkage, distortion, elastic deformation, camber, sweep, slope, waste for proper machining and burning and other phenomena that may make initial "in process" fabricating dimensions and material ordering dimensions different from the final product design dimensions shown on the Contract Drawings.

102. SHOP DRAWINGS.

102.1. Preparation. The Contractor shall prepare as soon as possible after the contract is signed, complete and accurate shop drawings of all structural steel, machinery and other details, and the connections thereof to the concrete masonry or other substructure parts.

102.2. Size and Type. Shop drawings shall be neatly drawn and clearly legible to produce microfilm negatives which conform to the U.S. Department of Defense specifications. Shop drawings shall be cut to a standard size of 22 x 36 inches and arranged to conform to the contract drawings. Failure to submit shop drawings of the required size will be cause for their return without examination. The margin line shall be drawn ½ inch from the top, bottom and right hand edges and 2 inches from the left hand edge to permit binding. The working space on these drawings will therefore be 21 inches by 33½ inches. A space 3 inches by 11 inches, the 11 inches being parallel to the length of the sheet, shall be reserved in the lower right hand corner for title and approval signature. The sheets shall be arranged so that as far as possible the notes will appear above each other near the right edge of the sheet. The drawings shall be arranged systematically within erection divisions or groupings and numbered consecutively in the lower right hand corner.
102.3. Information Required on Shop Drawings. The contract number and name, together with the Region and County in which the work is to be performed shall be clearly indicated on each sheet, together with the fabricator's shop order number for the work detailed on the sheet.

The shop drawings must contain a bill of material on the sheet that details the member. If the member has such proportions that more than one sheet is required to fully detail it, the complete bill of material may be placed on the last sheet of the group of sheets detailing the member. The bill of material must describe the details of material used in the fabrication of the member. In addition, primary stress carrying pieces shall be described by their mill order number (Line No. & Item No.) so that direct reference to the mill test report describing the steel may be made without difficulty. In lieu of this requirement, the Contractor may submit, after the material has been delivered to the shop, shop drawings which have been revised to include the heat numbers of each piece used in the work that is subject to primary stress.

When payment is to be made on a pound-price basis, the computed pay weight of each shipping unit shall be clearly marked on the shop drawing on which the unit is detailed.

102.4. Details.

102.4.1. A.A.S.H.O. Requirements. All Shop Drawings for bridges carrying highways shall be detailed in accordance with the provisions for design and workmanship of the current edition of the American Association of State Highway Officials, “Standard Specifications for Highway Bridges,” except as modified by the Contract Documents.

102.4.2. A.R.E.A. Requirements. All Shop Drawings for bridges carrying railroad tracks shall be detailed in accordance with the provisions for design and workmanship of the current edition of the American Railway Engineering Association Specifications for “Steel Railway Bridges,” except as modified by the Contract Documents.

102.4.3. Detailing for Welded Fabrication. All welding required by the Contract Documents shall be completely detailed on the Shop Drawings. All joints shall be detailed in conformance with the requirements of sub-section 203, “Welding” contained herein.

All welding details shall incorporate Standard Welding Symbols as described in AWS A 2.0 and shall conform to the requirements of sub-section 203, “Welding.”

The definition of welding terms used in this manual shall be interpreted in accordance with the definitions given in the current edition of “AWS Terms and Definitions” (AWS A 3.0).

102.4.4. Field Splices in Stringers and Girders. When the specific location for a bolted or welded field splice in stringers and girders is not shown on the Contract Drawings, the Contractor will be permitted to introduce splices at locations of his choice. Those locations are subject to the approval of the D.C.E.S.

Splices shall meet the following requirements:

102.4.4.1. The Contractor will have the option of providing either welded or bolted splices unless specific types of splices are required by the Contract Documents.

102.4.4.2. When the Contractor informs the D.C.E.S. of his selection of proposed bolted splice locations, the State will furnish the Contractor with the bolted splice design at each location. The Contractor shall detail the splice on Shop Drawings and submit them to the D.C.E.S. for approval.

When stringers or girders of any cross section are to be spliced by welding, the detailed welding procedure shall be submitted to the D.C.E.S. for his approval. The procedure shall be detailed on shop drawings and submitted prior to the fabrication of structural steel. The request for approval of the detailed field welding procedure including the method of support during welding shall be submitted directly to the D.C.E.S. All field welded splices shall be subjected to nondestructive testing in accordance with Section VI, Radiographic Inspection. The provisions of Article 204.5, “Shop Assembly of Field Welded Connections” shall apply.
102.4.4.3. Fill plates will not be permitted. Web and flange shop butt welds may be moved to extend the thicker plate so that bolted connections are made in materials of the same thickness. All manufacturing dimensional tolerances shall be controlled so that bolted splices may be properly assembled without distortion and without requiring fills.

102.4.4.4. The D.C.E.S. reserves the right to order, at no extra cost, a welded splice at any location where a bolted splice design will require high strength bolts in excess of eight inches long.

102.4.4.5. Butt welded field splices in stringers and girders shall be made by complete penetration groove welds which shall be radiographed as required by the Contract Documents.

102.4.4.6. Bolted designs shall use ASTM A325 High Strength bolts only. The design shall be based upon the allowable shear for a friction-type connection. Bolt lengths shall be such that threads are excluded from shear planes in the connection.

102.4.4.7. When a bolted splice is not completely detailed on the Contract Drawings at a specific location, no payment will be made for splice plates, bolts, nuts, washers or any increase in thickness of webs or flanges made necessary by the bolted splice requested by the Contractor and designed by the D.C.E.S.

102.4.5. Location of Shop Welded Splices in Fabricated Members. Shop welded splices may be located at points in fabricated members that are consistent with lengths of plate available from the mills. Welded joints should be located at points of reduced tensile stress, if this will not create additional labor or material costs for the Contractor.

When flanges or webs of welded plate girders are detailed on the Contract Drawings as a series of plates of varying thickness joined by butt welds, the Contractor may, for the purpose of eliminating butt welds, extend the length of the thicker plate to the end of the next thinner plate or to the end of the member if approved by the D.C.E.S. The extra material required by this procedure must be furnished at no cost to the State. The maximum thickness transition at any joint shall not exceed a ratio of 1 to 2. Web thickness ratios may exceed this limit if shown on the Plans.

If the contractor increases the thickness of the bottom flange plate at a bearing location, he shall maintain the original girdle elevation by making suitable compensating changes in the elevation or dimensions of the supports as approved by the D.C.E.S. In lieu of this, the Contractor may remove the increased thickness by machining the bottom flange plate at the bearing to maintain the original girdle elevation. The transition between the machined surfaces and the adjacent plate surface shall have a slope not greater than 1 on 2½.

102.4.6. Standard Details for Fabrication. Unless otherwise provided in the Contract Documents, the following Standard Practices shall apply:

102.4.6.1. Intermediate stiffeners for plate girders shall consist of single plates welded to the web and to the flange which is in compression at that point under all conditions of service loads. They shall be placed perpendicular to the top flange or to a tangent to the top flange at each location.

On interior stringers, intermediate stiffeners shall be located on alternate sides of the web except where they are used in conjunction with a longitudinal stiffener, in which case they shall be placed on one side of the web with the longitudinal stiffener on the other side. Unless otherwise specified on the Contract Plans, intermediate stiffeners shall be attached to fascia girders or stringers on the side of the web that is not exposed to view.

102.4.6.2. When structural steel is to be placed at a grade greater than five percent, bearing stiffeners and connection plates at the points of support shall be placed vertical.

102.4.6.3. Longitudinal stiffeners for plate girders shall be placed on one side of the web only. On fascia girders they shall be placed on the web surface exposed to view.
Longitudinal stiffeners shall be continuous between transverse stiffeners, if any, and shall be assembled full length using complete penetration groove welds before attachment to the web and transverse stiffeners. In general they will be limited to use on the compression areas of the web only.

Longitudinal stiffeners intersecting transverse stiffeners shall be fillet welded to the transverse stiffener. When the Contract Documents require longitudinal stiffener attachments to tension areas, the stiffener shall be continuous full length using complete penetration groove welds which shall be radiographically inspected as described in Section VI. The joint details for all intersecting attachments in tension areas shall be approved by the D.C.E.S.

102.4.6.4. The ends of all girders and beams shall be vertical after deadload deflection.

102.4.6.5. When the steel is to be erected to a grade of three percent or less, it will not be necessary to machine the top of the sole plate to a compensating bevel. No machining of the top of the sole plate will be required if the surface is plane and true as described in Article 202.5, "Machining of Contact Surfaces."

102.4.6.6. When the Contract Plans specify welded plate girders with horizontal curvature, the girders shall be fabricated using heat-curving procedures in accordance with Section V or by flame cutting the flanges to the required radius prior to assembly to the web. The camber for welded plate girders shall be provided by the D.C.E.S.

102.4.6.7. The horizontal curvature and camber if specified for rolled beams, shall be fabricated using only heat-curving procedures in accordance with Section V.

102.5. Approval of Shop Drawings. Shop drawings are required for all structural steel, except for rolled beam bridges not requiring fabrication or for miscellaneous steel, when specified in the Contract Documents. When the shop drawings prepared by the Contractor as specified are completed, triplicate reproductions shall be submitted to the D.C.E.S. who will review and indicate thereon corrections deemed necessary by the State.

The triplicate reproductions may be either three paper prints, or two paper prints and one sepia or other approved reproducible. If three paper prints are submitted, one set of paper prints, with corrections, indicated thereon will be returned to the Contractor. If two paper prints and one sepia are submitted, the set of sepia reproductions will be returned to the Contractor with the following stamp:

N. Y. S. D. O. Y. SEPIA REVIEW CHECKED DATE

Approved
Approved for Fabrication Without Weights
Approved - as - Noted
Disapproved
Submit Tracing for Approval Stamp
Correct Sepia and Resubmit
Make Indicated Changes to Tracing and
Submit for Approval Stamp

Approval is limited to Materials and type of Details. No Steel shall be shipped from the Shop until the Inspector is furnished a print made from the approved tracing.

*Does not apply when payment is not to be made on a pound-price basis.

As soon as the Contractor receives a reproducible marked "Approved," "Approved for Fabrication Without Weights," or "Approved-As-Noted," he is authorized to reproduce the drawing and furnish necessary copies to the shop and to the Inspector. If he agrees to the notations on the "Approved-As-Noted" drawings, he may begin the fabrication incorporating the required changes. If he feels that the notations on the drawing constitute "Extra Work" or "Disputed Work," the Contractor must notify the Department under the provisions of the Specifications For Disputed Work.
On Contracts involving one or more railroads, the Contractor shall furnish each Railroad Company with duplicate paper reproductions of the shop drawings at the same time triplicate reproductions are submitted to the D.C.E.S.

When the revisions marked on the shop drawings have been completed, the original reproducibles shall be submitted to the D.C.E.S. in a mailing tube for his approval stamp and signature. The Contractor shall carry out the construction in strict accordance with the approved drawings and shall make no further changes therein except with the written approval of the D.C.E.S. The D.C.E.S. approval shall not relieve the Contractor from his responsibility for errors that may exist in the shop drawings.

102.6. Detention of Shop Drawings. The D.C.E.S. shall be allowed two work days for the examination of each drawing in a set of shop drawings or ten work days minimum per set. A set of shop drawings shall be considered to be all drawings submitted by a given Contractor for a particular contract on any calendar day. If the shop drawings are detained for examination for a period longer than stated above, such detention will be taken into account when considering application by the Contractor for an extension of time for the completion of the contract. All shop drawings are time and date stamped as they are received and recorded in a log at the office of the D.C.E.S. This log shall be the basis for determining when drawings must be returned without adjustment of the completion date as described in this section.

The State will return corrected and/or approved drawings with the minimum possible delay. In order to expedite his work, the Contractor should indicate in his submittal his order of preference for the review and return of drawings and should submit all drawings in their order of importance to his construction program.

102.7. Disposal of Original Reproducibles. After the completion of the contract and before the acceptance thereof, the Contractor shall deliver to the D.C.E.S. all approved original reproducibles which shall thereafter remain the property of the State.

102.8. Reproduction of Approved Shop Drawings. The Contractor (or Fabricator) shall distribute prints of the approved shop drawings, as follows:

1 – Set to the Deputy Chief Engineer (Structures)
2 – Sets to the General Contractor
2 – Sets to the Regional Director of Transportation
2 – Sets to the designated Inspection Agency.

In addition to the above drawings, the Contractor shall submit one set of reproducibles made of approved durable stock to the Regional Director of Transportation.

For every Railroad Company or Public Agency involved in the contract, the Contractor shall furnish three (3) additional sets of prints, on paper, and one (1) set of approved reproducible shop drawings made by an acceptable process.

102.9. Cost of Shop Drawing Prints and Reproducibles. The cost of all shop drawing prints and reproducibles required by the specification shall be included in the price bid for the payment item requiring the drawings. Any prints and reproducibles requested beyond the number specified shall be furnished by the Contractor at cost.
SECTION II

FABRICATION

201. GENERAL

201.1. Minimum Shop Facilities for Fabrication. The Contractor shall provide sufficient lifting capacity, physical plant and equipment for the fabrication and painting of structural steel. A minimum of two overhead cranes shall be provided. The cranes in each working area shall have a combined rated capacity equal to the lifting weight of the heaviest assembly fabricated for shipment unless alternate lifting and turning facilities are approved by the D.C.E.S.

Lifting chains shall be provided with adequate softeners to prevent damage to the corners of material during lifting and turning. If hooks are used for lifting, they must have sufficient width of jaw and throat to prevent damage to the flanges or to the web-to-flange welds.

Spreader beams, or multiple cranes, must be provided for lifting plates and long slender members to prevent distortions from handling.

Shops shall have sufficient enclosed floor space to allow all flame-cutting, air carbon-arc gouging, assembly, welding and painting to be performed inside except that the shop assembly of field connections for trusses, girders and arches may be performed outside the shop buildings.

The D.C.E.S. will approve limited fabrication, welding and painting outside the shop, provided the fabricator has made provisions to insure that the quality of work produced outside the shop buildings will not be adversely affected by weather or other conditions.

All welding and painting shall be done in an area that is kept dry. Further, areas for automatic and semiautomatic welding shall be kept at a temperature not lower than 40°F for at least one hour before work begins and at all times when work is being performed. In painting areas, the steel shall be at a temperature not lower than 40°F upon application of paint and shall remain at least 40°F until the paint is dry.

Unless modified by other provisions of the Contract Documents, fully automatic welding equipment shall be provided for making all flange-to-web welds and for attaching all stiffener and connection plates to webs of welded plate girders. Web to flange welds in box girders, arches, towers and truss web and chord members shall be made by fully automatic welding equipment unless otherwise approved by the D.C.E.S. Semiautomatic (hand-guided) or fully automatic welding equipment shall be used for all other principal welds.

The use of the Manual Shielded Metal-Arc process shall be limited to welding connection plates to rolled beams, welding bearing assemblies, minor detail attachments, and other limited welding applications where the use of automatic or semiautomatic welding equipment is impracticable because of limited access, or the isolated location and short length of welds involved.

All welders using Gas Shielded Flux Cored-Arc Welding or Manual Shielded Metal-Arc Welding processes shall have access to a pneumatic chipping hammer or needle descaler and to an air carbon-arc gouger at all times.

201.2. Ordering of Materials. The Contractor shall bear all costs or damages which may result from the ordering of any materials prior to the approval of the shop drawings as described in sub-section 102 unless the State makes changes in the Principal Controlling Dimensions and Properties (Art. 101.5.) after the opening of bids.

201.3. Commencement of Shop Work. No shop work shall be started until the shop drawings have been approved. Any shop work started prior to the approval of shop drawings, shall be done at the Contractor's risk.
201.4. Workmanship and Finish. Workmanship and finish shall be first class and equal to the best practice in modern bridge shops. Shearing, chipping, flame cutting, and arc-air gouging shall be carefully and accurately done. All flame cut surfaces shall be produced using a mechanically guided torch unless otherwise approved by the D.C.E.S. Flame cut surfaces shall conform to the requirements of Paragraph 202.4.3. Flame cut surfaces produced by a manually guided torch, when allowed, shall be smoothed by machining or grinding. Reinforcement cuts shall be filleted to a minimum radius of 3/8 inch.

Surface roughness specified in microinches shall conform to the requirements in the American National Standard for Surface Texture (ANSI B46.1).

202. PREPARATION OF BASE MATERIAL.

202.1. General. All steel or other base metal shall be furnished in accordance with the provisions of the applicable material specification of the Contract Documents. This manual covers structural steel used in bridge and building construction that has a minimum specified yield point of 50 ksi or less.

202.2. Soundness of Plates and Shapes.

202.2.1. Laminar Defects at Edges and Ends. All plates and shapes shall be subject to a careful visual inspection of edges and ends for the presence of laminar discontinuities and inclusions. The shop inspector shall also determine by visual inspection that the steel contains no detrimental defects and that it meets the requirements of ASTM Designation A6 unless otherwise specified.

Rejection or repair of laminar discontinuities discovered in the edges of steel up to 4-inch maximum thickness during the plant inspection at the time of fabrication is described in Table 202.2 titled “Internal Soundness by Visual Inspection of Plate Cut Edges.” Laminar defects in the edges of shapes discovered by visual examination will be subject to repair or replacement as determined by the D.C.E.S.

Acceptance, rejection, or repair of steel greater than four inches thick that contains visible discontinuities in edges or ends will be determined under provisions established by the D.C.E.S.

202.2.2. Laminar Defects at Tension Groove Welds.

202.2.2.1. Detection of Defects. The following sequence will be used to determine if laminar defects are present at the boundary of tension groove welds that will require rejection and replacement, or repair, under the provisions of the Specifications.

202.2.2.1.1. If during visual inspection, laminar defects are discovered at any location in a plate or shape, the end two feet adjacent to the tension groove weld and the edge to be welded will be subject to magnetic particle inspection.

202.2.2.1.2. If during the magnetic particle inspection, laminar defects are discovered, Ultrasonic Testing will be used to search the end 6 inches of the plate or shape adjacent to the tension groove weld.

202.2.2.1.3. When Ultrasonic Testing is required, the test procedure described in par. 709.2 shall be used to determine if the laminar defects are reparable. This U.T. inspection shall be performed by the Contractor and witnessed by the inspector.

202.2.2.1.4. In addition to the Ultrasonic Test requirements, if it is found during magnetic particle inspection that the sum of laminar defect lengths at the boundary of the tension groove weld exceeds 15% of the total length of the joint, the steel shall be rejected for use as a boundary for a tension groove weld.
<table>
<thead>
<tr>
<th>Description of Discontinuity</th>
<th>Repair Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any discontinuity 1&quot; in length or less.</td>
<td>None – need not be explored.</td>
</tr>
<tr>
<td>Any discontinuity over 1&quot; in length and 1/8&quot; maximum depth.</td>
<td>None – depth should be explored by random spot grinding well faired in order not to create notches in the plate edge.</td>
</tr>
<tr>
<td>Any discontinuity over 1&quot; in length with depth over 1/8&quot; but not greater than 1/4&quot;.</td>
<td>Remove by grinding or by chipping or air carbon-arc gouging followed by grinding. The excavation shall be well faired in order not to create notches in the plate edge. If the removal of a discontinuity reduces the net cross section area of the plate by more than 5%, the resultant cavity shall be filled by welding.** See Note 3. Aggregate length of welding not over 20% of plate edge length being repaired.</td>
</tr>
<tr>
<td>Any discontinuity over 1&quot; in length with depth over 1/4&quot; but not greater than 1/2&quot;.</td>
<td>Completely remove and weld. Aggregate length of welding not over 20% of plate edge length being repaired.** See Note 3.</td>
</tr>
<tr>
<td>Any discontinuity over 1&quot; in length with depth greater than 1/2&quot;.</td>
<td>Subject to approval by the Engineer. Gouge out to 1&quot; and block off by welding. See Note 3. Aggregate length of welding not over 20% of plate edge length being repaired.**</td>
</tr>
</tbody>
</table>

*Defects exceeding this length require the approval of the engineer before being repaired.

**Repair welding of tension members will be subject to ultrasonic inspection.

NOTES:
1. This specification applies only to plate edges which will not be joined by welds subject to calculated stress. This specification does not apply to any plate that is subject to stress across its thickness (i.e., in “Z” direction).
2. Length of a defect is the visible long dimension on a plate cut edge. Depth is the distance that the defect extends into the plate from the cut edge.
3. All manual welding shall be performed by qualified welders using low-hydrogen electrodes. Submerged arc welding and Flux Cored arc welding with external gas shielding may also be used with approved procedures. Cavities resulting from the removal of discontinuities shall be prepared prior to repair welding with a minimum radius of 3/4 inch and a minimum included angle of 20 degrees. When plate thickness is not sufficient for such preparation, repair welding will not be permitted.
202.2.2. Repair of Defects. When the above inspection procedures reveal rejectable defects at the boundary of a tension groove weld, one of the following methods of repair will be approved in lieu of replacement of the entire plate:

202.2.2.1. The end portion of the plate may be removed and replaced to eliminate the defective portion of the plate. The replacement material may be obtained from stock if the heat identity is known and acceptable mill test reports are available. The minimum length of added plate shall be 3 feet unless otherwise approved by the D.C.E.S. A longer plate may be required to ensure an area free of laminations at the boundary of the additional tension groove weld. The additional butt weld resulting from the added plate shall be subject to radiographic inspection in addition to the originally detailed weld inspection required by the Specifications. The direction of rolling of the replacement plate shall be parallel to the length of the member. The repair procedure shall be submitted to the D.C.E.S. for approval and shall be shown as a revision to the approved shop drawings prior to the final acceptance of the repair.

202.2.2.2. When the sum of all laminar defects at the boundary of the tension groove weld does not exceed 30% of the length of the joint, the defective portion of the end of the plate may be excavated by air carbon-arc gouging and the laminated steel replaced by sound weld metal. For approval of this procedure, the Ultrasonic Testing must be extended for six inches beyond the limits of the gouged area. In this additional test, the end of the gouge shall be treated as the boundary of a tension groove weld and the plate shall be reevaluated as described in par. 202.2.2.1.

The cavity in the edge of the plate and any excavation from a plate surface shall have a minimum radius of 1/8 inch at the root and the sides shall slope back to provide a minimum angle of 20°. An approved welding procedure shall be used to fill the repair excavation and the excess weld metal shall be ground flush. At the completion of welding, the end six inches shall be retested by the Ultrasonic Test procedure described in this Manual to insure the complete removal of the laminar defects. The area repaired by welding shall also be inspected for weld defects by radiographic inspection.

The repair procedure shall be submitted to the D.C.E.S. for approval prior to the initiation of repairs.

The cost of all work and materials required for the repair of laminar defects at the boundary of tension groove welds shall be included in the price bid for this item.

202.3. Straightening Material Prior to Fabrication. All deformed structural material shall be properly straightened prior to being laid out and worked in the shop. Sharp kinks and bends shall only be straightened with the approval of the D.C.E.S. Main material (i.e., components of principal supporting members subject to calculated stress) shall not be bent cold without the approval of the D.C.E.S. Heat straightening shall be done in accordance with the provisions for Heat-Curving and Cambering of Rolled Beams and Welded Plate Girders, Section V.

202.4. Preparation of Material for Assembly.

202.4.1. Surfaces and edges to be welded shall be smooth, uniform, and free from fins, tears, cracks and other defects which would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, grease or other foreign material that will prevent proper welding or produce objectionable fumes. Mill scale that withstands vigorous wire brushing, a light film of drying oil, or a thin rust inhibitive coating or anti-spadder compound may remain except that all mill scale shall be removed from the surfaces on which flange-to-web welds are to be made by any of the approved welding processes. This provision shall apply to all stringers, beams, bridge columns, bent, towers, rigid frames, arches, truss chords and truss web members. The provision for removal of all mill scale prior to making web-to-flange welds shall not apply to secondary members, building columns or to members subjected to general blast cleaning prior to welding, where essentially all mill scale has been removed and no harmful rusting has occurred subsequent to blast cleaning, as determined by the Inspector. No mill scale shall be permitted to remain in the boundary of a groove weld subject to tensile stresses resulting from the design loads.
202.4.2. Unless otherwise specified, edges of material thicker than specified in the following list shall be trimmed as required to produce a satisfactory welding edge wherever a weld along the edge is to carry calculated stress. (See Paragraph 202.4.1)

Sheared edges of material thicker than ........................................ 3/4 in.

Rolled edges of plates (other than
Universal Mill plates) thicker than ........................................ 3/8 in.

Toes of angles or rolled shapes (other than
wide flange sections) thicker than ........................................ 5/8 in.

Universal Mill plates or edges of flanges of
wide flange sections thicker than ........................................ 1 in.

The form of edge preparation for butt joints shall conform to the requirements of par. 203.11.7 through 203.11.9 except as modified by par. 203.11.4.

202.4.3. Steel and weld metal may be oxygen cut, provided a smooth and regular surface free from cracks and notches is secured, and provided that an accurate profile is secured by the use of a mechanical guide. Free-hand oxygen cutting shall be done only where approved by the D.C.E.S. as provided in par. 201.4.

202.4.3.1. In all oxygen cutting, the cutting flame shall be so adjusted and manipulated as to avoid cutting beyond (inside) the prescribed lines. Roughness of oxygen cut surfaces shall not be greater than that defined by the American National Standard surface roughness value of 1.000 for material up to and including 4 inches thick and 2,000 for material greater than 4 to 8 inches thick. Roughness exceeding these values and occasional notches or gouges not more than 3/16 inch deep, on otherwise satisfactory surfaces, shall be removed by machining or grinding. Cut surfaces and edges shall be left free of slag. Correction of defects shall be limited to the oxygen cut surfaces with a slope not exceeding 1 in 10. Defects in oxygen cut edges shall be repaired by welding for occasional notches or gouges less than 7/16 inch deep for material up to 4 inches thick and less than 5/8 inch deep for material over 4 inches thick. Such weld repairs shall be made by suitably preparing the defect, welding with low hydrogen electrodes 5/32 inch in diameter, observing the applicable requirements of sub-section 203 and grinding the completed weld smooth and flush with the adjacent surface to produce a workmanlike finish. A repair procedure must be submitted to the D.C.E.S. for approval to repair defects which exceed these limits.

All welded repairs to main material subject to tensile stress shall be subject to ultrasonic or radiographic inspection as determined by the D.C.E.S.

202.4.3.2. Reentrant corners, except for the corners of weld access cope holes adjacent to a flange, shall be filleted to a radius of not less than 3/16 inch. The fillet and its contiguous cuts shall meet without offset or cutting past the point of tangency.

202.4.4. Machining, air carbon-arc gouging, chipping, or grinding may be used for joint preparation, back gouging, or the removal of defective work or material. All air carbon-arc gouged surfaces shall be ground after gouging to remove any carbon pick-up.

202.4.5. Edge Preparation. All welded plate girder, box girder and box arch webs greater than 3/8 inch thick shall be prepared for welding by flame cutting to the prescribed lines. All flange plates may be furnished with flame cut edges which have the corners chamfered at least 1/6 inch by grinding or with universal mill edges unless the Contract Documents prohibit the use of universal mill plate. All plates in welded sections for truss web and chord members shall have their longitudinal edges prepared by flame cutting.

Gusset plates and other connections welded parallel to lines of stress in tension members shall have the sides parallel to the lines of stress flame cut whenever their thickness exceeds 3/8 inch.
Stiffeners and connection plates welded transverse to girder webs and flanges may be furnished with sheared edges provided their thickness does not exceed 3/8 inch. Universal mill plate may be used provided its thickness does not exceed 1.0 inch. All other stiffeners and connection plates shall be furnished with flame cut edges.

202.5. Machining of Contact Surfaces.

202.5.1. Bearing Surfaces. The surface finish of bearing and base plates and other bearing surfaces which are to come in contact with each other or with concrete shall meet the American National Standard for Surface Roughness as defined in ANSI B46.1, Surface Roughness, Waviness and Lay, Part I.

Steel slabs or plates in contact with a concrete surface:
   ANSI 2000
Heavy plates in contact as part of bearing assemblies which are welded:
   ANSI 1000
Ends of compression members, bearing stiffeners and fillers in compression:
   ANSI 500
Rollers and Rockers:
   ANSI 250
Pins, Pin Holes, Rotating Portion of Top of Rockers and Rocker Sockets in Sole Plates:
   ANSI 125
Sliding Bearings:
   ANSI 125

Sliding bearings shall be machined so that the lay of the cut is parallel to direction of movement.

Machine surfaces shall be plane and true conforming accurately to the dimensions shown on the plans.

Parts in bearing shall have uniform even contact with the adjacent bearing surface when assembled. The maximum gap between bearing surfaces shall be 0.040 inches unless a closer tolerance is specified.

Base and sole plates which are plane and true and which have a surface roughness not exceeding the above tabulated values need not be machined, however, sliding surfaces of base plates must be machined.

Surfaces of fabricated members shall not be machined until all fabrication on that particular assembly or sub-assembly is complete.

202.5.2. Abutting Joints. Abutting compression members shall be machined as specified above unless the Contract Documents indicate otherwise. Ends of abutting tension members shall be machined or machine burnished to an ANSI surface roughness value of 1,000 to secure close and neat but not contact fitting joints. When the design is based upon transmitting all stress through the fasteners, the Contract Document may detail all joints open 1/2 inch maximum in which case ends of members will be treated as abutting tension members regardless of direction of stress.

202.5.3. End Connection Angles. End connection angles of floor beams and stringers shall be flush with each other and accurately set as to position and length of member. In general, end connection angles shall not be finished unless required by the Contract Documents. However, faulty assembling and connecting may be cause for requiring them to be milled, in which case their thickness shall not be reduced by more than 1/16 inch, nor shall their fastener bearing value be reduced below design requirements.


202.6.1. Punched Holes. When reaming is not required, holes may be punched full size under the following conditions:

   (a) When the metal has a specified minimum yield point less than 40,000 psi and a thickness of 3/8 inch or less.
(b) When the metal has a specified minimum yield point less than 50,000 psi and a thickness of 5/8 inch or less.

Holes required to be reamed shall be sub-punched or sub-drilled and reamed.

202.6.2. Size of Punched Holes. Full-size punched holes shall be 1/16 inch larger than the nominal diameter of the fastener. The diameter of the die shall not exceed the diameter of the punch by more than 1/16 inch. Holes must be clean cut, without torn or ragged edges. If any holes must be enlarged to admit fasteners, they shall be reamed in accordance with the provisions of the Contract Documents.

202.6.3. Accuracy of Punched Holes. The punching of holes shall be so accurately done that, after assembling the component parts of a member or an assembly of connecting members, a cylindrical pin 1/8 inch smaller than the nominal diameter of the punched hole may be passed through at least 75 of any group of 100 contiguous holes in the same surface or a like portion for any group of holes. If this requirement is not fulfilled, the badly punched pieces shall be rejected. If any such hole will not pass a pin 3/16 inch smaller than the nominal diameter of the punched hole, this shall be cause for rejection. The requirement for the fitting of sub-size pins during assembly is to provide the minimum offset of holes between assembled plies and to insure that if reaming is performed as required by the specifications, all cold worked material will be removed from surfaces of the hole. Reaming shall remove all cold worked (punch sheared) material from the boundaries of sub-punched and reamed holes. The depth of removal shall be 1/16 inch minimum. If the accuracy of sub-punch work will not guarantee this hole quality when reamed, the amount of metal to be removed by reaming shall be increased from the minimum amount stated in Par. 202.6.5, Sub-Punched and Reamed Holes, a sufficient extra amount to insure compliance with this specification. No interchange of reamed or drilled parts will be permitted.

202.6.4. Drilled Holes. Drilled holes shall be 1/16 inch larger than the nominal diameter of the fastener. Burr s on the surfaces shall be removed by a method which leaves the hole free of burrs inside and out. The method shall not dish-out (reduce its thickness) the metal in the vicinity of the hole.

202.6.5. Sub-Punched and Reamed Holes. Holes for fasteners having diameters greater than 3/8 inch shall be punched 3/16 inch smaller than the nominal diameter of the fastener and for fasteners having diameters 3/8 inch or less shall be punched 1/16 inch less than the nominal diameter of the fastener. The punch and die shall have the same relative sizes as specified for full-size punched holes. After punching, the holes shall be reamed to a diameter 1/16 inch larger than the nominal diameter of the fastener.

Burr s resulting from reaming shall be removed as stated in Par. 202.6.4, Drilled Holes.

Reaming of fastener holes shall be done with twist drills or with taper reamers. Reamers preferably shall not be guided by hand. No oil or grease shall be used as a lubricant unless all such material is removed by solvent cleaning before final assembly, painting and shipment.

202.6.6. Accuracy and Quality of Reamed and Drilled Holes. Holes drilled from the solid shall be accurately placed, perpendicular to the faying surface, cylindrical, and shall show no offset between adjacent plies.

Holes which are to be reamed shall have been accurately sub-punched or sub-drilled and the assembled parts before reaming shall conform to the requirements specified for Par. 202.6.3, Accuracy of Punched Holes. After reaming, holes shall be perpendicular to the faying surface and 75 of any group of 100 contiguous holes in the same surface or a like proportion of any group of holes shall show no offset between plies or elongation of the hole greater than 1/32 inch. The remainder of the holes shall not be elongated or show an offset between plies greater than 1/16 inch.

202.6.7. Drifting of Holes. Any drift pinning done during assembly shall be only the minimum necessary to bring the parts into position, and not sufficient to enlarge the holes or distort the metal.

202.6.8. General Reaming of Trusses. Unless otherwise stated in the Contract Documents, all truss members regardless of type or size shall be subject to general reaming.
When general reaming is required, all rivet or bolt holes in main members shall be sub-punched and reamed, or drilled from the solid. This requirement shall not apply to holes in top and bottom chord lateral members, truss sway bracing, and to the lateral plates, connection angles, etc., connecting these members to the main members of the structure. Connection plates or other parts acting both as main member material and secondary (lateral, sway bracing, etc.) member material shall have sub-punched and reamed or drilled holes in locations engaging similar holes in main members.

Reaming or drilling shall be done after mating pieces are assembled to the proper geometric lines and firmly bolted together. No interchange of reamed or drilled parts will be permitted.


202.7.1. General. The material furnished for pins and rollers shall conform to the following requirements:

When pins and rollers are designed for a minimum yield stress of 36 ksi, the material furnished shall conform to the requirements of ASTM Designation A235 Class E.

When pins and rollers are designed for a minimum yield stress of 50 ksi, the material furnished shall conform to the requirements of ASTM Designation A235, Class G.

Any pin or roller greater than twelve (12) inches in diameter shall be furnished in conformance with the requirements of ASTM Designation A237, Class A.

Pins and rollers shall be accurately manufactured to the dimensions shown on the plans. The surface finish shall be as required by the Specifications. Pins larger than 9 inches in diameter shall have a hole not less than 2 inches in diameter bored longitudinally through their centers. The hole shall be bored before the pin is subjected to heat treatment. Boring shall be conducted in a manner that will prevent injury to the pin. Pins which contain interior defects shall be rejected. The minimum radius on any reentrant cut machined in a pin or roller shall be 1/8 inch.

202.7.2. Boring Pin Holes. Holes for pins shall be bored true to detail dimensions, smooth and straight, normal to the axis of the member and parallel with any other interconnected pin hole unless otherwise required. A finishing cut shall always be made. The length outside to outside of holes in tension members and inside to inside of holes in compression members shall not vary from detailed dimensions more than 1/32 inch. Boring of holes in fabricated members shall be done after the riveting, bolting or welding is completed.

202.7.3. Pin Clearances. The diameter of the pin hole shall not exceed that of the pin by more than .020 inch for pins 5 inches or less in diameter, or .035 inch for larger pins.

202.7.4. Pin Threads. Pin threads shall make close fits in the nuts and shall meet the American National Standards Institute requirements for unified screw threads (ANSI B1.1) except that for diameters greater than 1/4 inches, pins shall be made with 6 threads to the inch.

202.7.5. Pilot and Driving Nuts. Two pilot nuts and two driving nuts shall be furnished for each size of pin, unless otherwise specified.

202.8. Bronzed Surfaced Expansion Bearings. Bronzed surfaced bearings shall be fabricated as follows:

The bronze surfacing shall be deposited on the steel base plate by the Oxy-Acetylene or the Manual Shielded Metal-Arc-Welding process.

The bronze electrodes and/or filler metal shall be of a size and type approved by the D.C.E.S. Electrodes conforming to AWS A5.6 Classification E CuAl-A2 and E CuAl-B are acceptable for SMAW welding.

A suitable flux shall be used when the Oxy-Acetylene welding process is utilized. The type of flux shall be approved by the D.C.E.S.
The surface of the steel base plate that is to receive the bronze deposit shall be thoroughly cleaned of all dirt, oil, grease, mill scale and oxides by grinding or sandblasting prior to making the deposit.

A sufficient thickness of bronze shall be deposited to allow machining to a minimum retained thickness of 3/32 inch. Upon completion of machining and polishing, the finished surface of the bronze shall show no evidence of cracks, slag, or porosity exceeding the limits specified herein. Unmachined low spots and porosity not to exceed .05 inch in diameter will be allowed in the finished surface provided that the total area of such defects does not exceed .05 percent of the total area of bronze on any one plate and further provided that the total area of such defects in any square inch of the finished surface shall not exceed .01 square inches. Low spots, porosity, voids or holidays larger or more numerous than stated above may be repaired by grinding to sound metal and depositing additional bronze in the defects followed by remachining to the required dimensions.

Warping of the plate shall be counteracted by bending the steel plate in the opposite direction to which warping will take place prior to making the deposit. Any warp remaining in the piece after welding and cooling shall be removed prior to machining.

The bronze surface shall be machined as a “sliding bearing” under the provisions of Art. 202.5, Machining of Contact Surfaces.

At the Contractor’s option, bronze surfaced expansion bearings may be fabricated by welding ¼ inch thick bronze plate or 1/8 inch thick bronze sheet to metal backing. The bronze shall conform to ASTM B100, Alloy No. 510, Rolled Copper-Alloy Plate, unless otherwise specified. Attachment shall be by fillet welds or a combination of fillet welds and plug welds or by brazing as approved by the D.C.E.S. If the bronze surface is plane and true within .010 inch after welding, there need be no machining of the bronze surface. Machining shall not reduce the bronze thickness to less than 3/32 inch at any location.

203. WELDING.

203.1. General.

203.1.1. The provisions of this sub-section are intended to describe the welding of structural steels that have a specified minimum yield point not exceeding 50,000 psi. Higher strength steel or steels not listed in the Material Specification for Structural Steel, will be subject to additional requirements as listed in the Contract Documents or may be specified by the D.C.E.S. during approval of the welding procedure specification if the steel was proposed by the Contractor.

203.1.2. ALL WELDERS AND WELDING OPERATORS SHALL BE QUALIFIED BY TESTS PRESCRIBED IN SECTION IV.

203.1.3. Welders shall be provided firm footing at all times. When it is necessary to weld from platforms above the ground, such platforms shall be rigidly braced to prevent movement of the platform during the welding operation.

203.2. Base Metals.

203.2.1. Steel to be welded shall conform to the requirements of the latest edition of one of the following material specifications:

203.2.1.1. Specifications for Structural Steel (ASTM A36)

203.2.1.2. Specifications for High-Strength Low-Alloy Structural Manganese Vanadium Steel (ASTM A441)

203.2.1.3. Specifications for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes (ASTM A500)

203.2.1.4. Specifications for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing (ASTM A501)
203.2.1.5. Specifications for High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 inches thick (ASTM A588).

203.2.2. When an ASTM A242 type of low-alloy structural steel is considered for use, it shall be made the subject of a special investigation as to weldability by the D.C.E.S., and the D.C.E.S. shall specify all pertinent information covering material, design and workmanship not covered by these Specifications.

203.2.3. When a structural steel other than those listed above is approved and such steel is proposed for welded construction, the weldability of the steel and the procedure for welding it shall be established by qualification tests in accordance with the requirements of Section IV and such other requirements as prescribed by the D.C.E.S.

203.2.4. Combinations of any of the steel base metals listed in par. 203.2.1 may be welded together. In joints involving combinations of base metals, welding preheat shall be in accordance with Table 203.5 for the higher strength steel being welded.

203.3. Approved Welding Processes.

203.3.1. The following welding processes shall be used for all welding unless other processes are approved by the D.C.E.S. on the basis of acceptable results of procedure qualification tests:

- Manual Shielded Metal-Arc Welding (SMAW)
- Submerged Arc Welding (SAW)
- Flux Cored-Arc Welding with External Carbon Dioxide Gas Shielding (FCAW)
- Electroslag Welding (EW)

All SMAW shall be performed using low-hydrogen electrodes as described in this specification. When FCAW is used, additional shielding shall be obtained from externally supplied carbon dioxide gas. EW will be permitted only in compression areas of bridge members and in buildings unless otherwise approved by the D.C.E.S.

203.4. Filler Metal Requirements.

203.4.1. The D.C.E.S. maintains a file of manufacturers' certified test results of filler metal qualification tests qualifying electrodes and flux for SAW, FCAW, EW and SMAW.

If the electrode or wire and flux combination to be used is not listed in this manufacturers' certification file or if the data contained therein is more than one year old because the manufacturer has failed to voluntarily submit the required certified test results, the Contractor will be required to furnish the Inspector with manufacturers' certified test results for each lot of electrode and flux used in the work.

This certification provides only for the acceptance of the electrode and flux. The welding procedure shall be qualified in accordance with the provisions of Section IV.

203.4.2. The electrode, electrode-flux combination, or grade of weld metal for complete joint penetration or partial joint penetration groove welds subject to shear stress and for fillet welds in shear may be of a lower strength than that required to match the base metal, provided the weld metal meets the stress requirements, as determined by the D.C.E.S. Under some conditions improved ductility is preferred to yield stress that matches the base metal.

Over matching of weld metal, i.e., when the weld metal is significantly stronger than the base metal is undesirable.

Over matching of weld metal can be one of the major contributors to lamellar tearing when the weld residual stresses stress the base metal in the short transverse “z” direction. The D.C.E.S. may disapprove welding processes electrodes and fluxes, that will cause serious overmatching in his opinion.
203.4.3. When special corrosion resistant characteristics are required for welding ASTM A588 and A242 steel, electrodes conforming to the requirements of the latest edition of the "Specification for Low-Alloy Steel Covered Arc-Welding Electrodes" (AWS A5.5) Classifications E8016-C3 or E8018-C3 shall be used for all manual welding. All other applications using automatic or semiautomatic processes shall be approved by the D.C.E.S.

In multi-pass welds, the weld may be deposited such that at least two layers on all exposed surfaces and edges are deposited with an approval filler metal meeting the corrosion resistant requirements as described above.

Where exposed, unpainted applications of ASTM A242 and A588 steel require weld metal with atmospheric corrosion resistance similar to that of the base metal but an exact color match is not required, the following procedure may be used, providing the welding procedure is approved by the D.C.E.S.

**SHIELDED METAL-ARC** — Single pass fillet welds up to ¾ inch maximum and groove welds made with a single pass or with a single pass each side may be made using an approved E70XX low hydrogen electrode.

**SUBMERGED-ARC** — Single pass fillet welds up to 5/16 inch maximum and groove welds made with a single pass or a single pass each side may be made using an approved F71-XXXX electrode-flux combination.

**FLUX CORED-ARC** — Single pass fillet welds up to 5/16 inch maximum and groove welds made with a single pass or a single pass each side may be made using an approved E701-1 electrode.

203.4.4. All electrodes, wire and flux shall be packaged, dried and stored in accordance with Articles 203.6 through 203.9.

203.5. Preheat & Interpass Temperature Requirements. With the exception of Electroslag welding, preheat and interpass temperatures shall conform to the requirements of Table 203.5 for the higher strength steel being welded.

### TABLE 203.5

<table>
<thead>
<tr>
<th>Thickness of Thickest Part at Point of Welding — Inches</th>
<th>ASTM A36</th>
<th>ASTM A588</th>
<th>ASTM A41</th>
<th>A500</th>
<th>A501</th>
<th>A242 (Weldable Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To ¾, Incl.</td>
<td>50°F</td>
<td>100°F</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Over ¾ to 1½ Incl.</td>
<td>70°F</td>
<td>200°F</td>
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<tr>
<td>Over 1½ to 2½ Incl.</td>
<td>150°F</td>
<td>300°F</td>
<td></td>
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<tr>
<td>Over 2½ Incl.</td>
<td>225°F</td>
<td>350°F</td>
<td></td>
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</tr>
</tbody>
</table>

**NOTES:**

1. When the base metal is below the temperature listed for the welding process being used and the thickness of material being welded, it shall be preheated (except as otherwise provided) in such manner that the surface of the parts on which weld metal is being deposited are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded, but not less than 3 inches, both laterally and in advance of the welding. The preheat shall extend 3 inches minimum in the through thickness direction. Preheat and interpass temperatures must be sufficient to prevent crack formation. Temperature above the minimum shown may be required for highly restrained welds. PREHEAT & INTERPASS TEMPERATURES AND HEAT INPUT employed shall be such that the hardness of the heat affected zone shall not exceed R_c 27.

2. In joints involving combination of base metals, preheat shall be as specified for the higher strength steel being welded.

3. All field welding shall be done with a minimum preheat and interpass temperature of 150°F. Field welding shall not be done when the ambient temperature is lower than 0°F.

4. Crack repair procedures shall include higher preheat temperature, controlled interpass temperature, and post heating as approved by the D.C.E.S.
203.6. Requirements for Manual Shielded Metal-Arc Welding.

203.6.1. Electrodes for Manual Shielded Metal Arc Welding Electrodes for SMAW shall conform to the requirements of the latest edition of “Specifications for Mild Steel Covered Arc Welding Electrodes” (AWS A5.1) or to the requirements of the latest edition of “Specifications for Low Alloy Steel Covered Arc Welding Electrodes” (AWS A5.5). Only classification E7018, E7028, E8016-C3 or E8018-C3 shall be used.

203.6.2. All SMAW electrodes shall be furnished in hermetically sealed containers and shall be dried for at least two hours, but not to exceed four hours between 500 and 550°F before they are used. After drying, electrodes may be placed in a storage oven held continuously at a temperature of at least 250°F until used in the work. Electrodes not used within four hours from the time they are removed from the drying or storage oven shall be redried for one hour minimum at a temperature between 700 and 800°F or shall be discarded and not used in the work. Under high humidity conditions this limit of four hours may be reduced as determined by the D.C.E.S. or the inspector. Redrying of electrodes will only be permitted if the Contractor has the proper equipment for controlled drying at the temperatures specified above. Electrodes which have been wet shall not be redried or used under any condition.


203.6.3.1. The work shall be positioned for flat position welding whenever practicable. This process shall be operated using DC reverse polarity unless otherwise approved by the D.C.E.S.

203.6.3.2. The classification and size of electrode, arc length, voltage and amperage shall be suited to the electrode, thickness of the material, type of groove, welding position and other circumstances attending the work.

203.6.3.3. The maximum size of electrode shall be as follows:

(a) 1/4 inch for all welds made in the flat position, except root passes.
(b) 1/4 inch for horizontal fillet welds.
(c) 5/32 inch for welds made in the vertical and overhead positions.
(d) 3/16 inch for root passes of groove welds and for all other welds not included under (a), (b), and (c) above.

203.6.3.4. The maximum thickness of layers subsequent to the root pass in fillet welds and of all layers in groove welds shall be:

(a) 1/4 inch for root passes of groove welds.
(b) 1/8 inch for subsequent layers of welds made in the flat position.
(c) 3/16 inch for subsequent layers of welds made in the vertical, overhead and horizontal positions.

The minimum size of a root pass shall be such as to prevent cracking.

203.6.3.5. The maximum size fillet weld which may be made in one pass shall be:

(a) 3/8 inch in the flat position.
(b) 5/16 inch in horizontal or overhead positions.
(c) 1/2 inch in the vertical position

203.6.3.6. In welding in a vertical position, the progressions for all passes shall be upwards. Vertical-down welding techniques shall not be permitted for any purpose.

203.6.3.7. Complete joint penetration groove welds made without the use of steel backing shall have the root arc-air gouged to sound metal before welding is started from the second side. Heat input and preheat must be maintained within the specified requirements when welding A588 steel.
203.6.3.3. Minimum preheat and interpass temperatures shall be maintained for all steels. As a further attempt to control minimum heat inputs for all steels being welded, the minimum size of electrode for Manual Shielded Metal Arc Welding shall be 5/32 inch.

203.7. Requirements for Submerged Arc Welding.

203.7.1. Definitions

203.7.1.1. Single electrode means one electrode connected exclusively to one power source which may consist of one or more power units.

203.7.1.2. Parallel electrode means two electrodes connected electrically in parallel exclusively to the same power source. Both electrodes are usually fed by means of a single electrode feeder. Welding current, when specified, is the total for the two electrodes.

203.7.2. General Requirements.

203.7.2.1. All Welding Procedures for submerged arc welding shall be qualified in accordance with the provisions of Section IV.

203.7.2.2. Submerged arc welding may be performed with one or more single electrodes, one or more parallel electrodes, or combinations of single and parallel electrodes. The spacing between arcs shall be such that the slag cover over the weld metal produced by the leading arc does not cool sufficiently to prevent the proper weld deposit of a following electrode. Submerged arc welding with multiple electrodes may be used for any pass of a groove or fillet weld.

203.7.2.3. The following articles governing the use of submerged arc welding are suitable for any steel included in Article 203.2. Considerations must include the additional heat input produced in simultaneous welding on the two sides of a common member. Electrode spacing orientation and weld travel speed shall be regulated to prevent bridging (undesirable base metal melting) and hot cracking.

203.7.2.4. The maximum size of electrodes shall not exceed 5/8 inch diameter.

203.7.2.5. Surfaces on which submerged arc welds are to be deposited and adjacent faying surfaces shall be clean as specified in Article 202.4 and shall be free of moisture.

203.7.2.6. All bridge welds detailed as complete penetration groove welds and not required to be fused into steel backing shall have the root of the initial first side weld arc-air gouged to sound weld metal before welding is started from the second side. For any building weld that requires a specific root penetration, the contractor shall make a sample joint and provide a macroetched cross section to demonstrate that the proposed welding procedure will attain the required root penetration without back gouging. The D.C.E.S. at his discretion may accept a radiograph of a test joint or recorded evidence in lieu of the test specified in this paragraph. Nondestructive tests may be employed to assure penetration is achieved in the work.

203.7.2.7. Neither the depth nor the maximum width in the cross section of weld metal deposit in each weld pass shall exceed the width at the surface of the weld pass (see Figure 203.7 a and b). This requirement may be waived if testing to the satisfaction of the D.C.E.S. has demonstrated that such welds exhibit freedom from cracking. Such testing shall be as directed by the D.C.E.S.

203.7.2.8. Tack welds in the way of fillet welds 3/8 inch or smaller in size, or in the root of joints requiring specific root penetration, shall be sufficiently small that they do not produce objectionable changes in appearance of the weld surface or result in decrease in penetration; otherwise they shall be removed or reduced in size by any suitable means prior to welding. Tack welds in the root of a joint with steel backing less than 5/16 inch thick shall be removed or made continuous for the full length of the joint using low-hydrogen electrodes.
203.7.3. Electrodes and Flux for Submerged Arc Welding.

203.7.3.1. The bare electrodes and flux used in combination for submerged arc welding of steels shall conform to the requirements in the latest edition of the “Specification for Bare MILD Steel Electrodes and Fluxes for Submerged Arc Welding” (AWS A5.17), Classification F71XXX. A shop welded procedure qualification test described in subsection 401 shall demonstrate the performance of the wire-flux combination when welding with shop equipment using the approved shop welding procedure specification.

203.7.3.2. If required by Article 203.4, the Contractor shall furnish manufacturers certifications that the electrode and flux combination will meet the requirements of the specified classification.

203.7.4. Condition of Flux

203.7.4.1. Flux used for submerged arc welding shall be non-hygrosopic dry and free of contamination from dirt, mill scale, or other foreign material. All flux shall be purchased in packages capable of being stored under normal conditions for at least six months without such storage affecting its welding characteristics or weld properties. Flux from damaged packages shall be discarded or shall be dried before use at a minimum temperature of 250°F for one hour. Flux shall be placed in the dispensing system immediately upon opening a package or if used from an opened package, the top one inch shall be discarded. Flux that has been wet shall not be used. Flux fused in welding shall not be reused.

203.7.5. Procedures for Submerged Arc Welding with Single Electrode

203.7.5.1. All submerged arc welds except fillet welds shall be made in the flat position. Fillet welds may be made in either the flat or horizontal position except that single pass fillet welds made in the horizontal position shall not exceed 5/16 inch.

203.7.5.2. The thickness of weld layers, except root and surface layers, shall not exceed ¼ inch. When the root opening is ½ inch or greater, a multiple pass split-layer technique shall be used. The split-layer technique shall also be used in making multiple pass welds when the width of the layer exceeds 5/8 inch.
203.7.5.3. The welding current, arc voltage and speed of travel shall be such that each pass will have complete fusion with the adjacent base metal and weld metal and there will be no overlap or undue undercutting. The maximum welding current to be used in making a groove weld for any pass that has fusion to both faces of the groove shall be 600A (amperes) except that the final layer may be made using a higher current. The maximum current to be used for making fillet welds in the flat position shall be 1,000A.

203.7.5.4. Where required by the D.C.F.S., a sample joint, having the same cross section as the joint to be used in construction and a length of at least 1 ft., shall be welded with the electrode, flux, current, arc voltage and speed of travel that are proposed to be used, and a macroetched cross section of the welded joint shall be prepared as a demonstration that the requirements of Para. 203.7.2.3, 203.7.2.6, 203.7.2.7, 203.7.5.2, and 203.7.5.3 will be met. When welding current, arc voltage and speed of travel are established by a test made in accordance with the requirements of this paragraph, they shall be kept within the limitation of variables as given in Section IV.

203.7.6. Procedures for Submerged Arc Welding with Multiple Electrodes

203.7.6.1. Submerged arc welds with multiple electrodes, except fillet welds, shall be made in the flat position. Single-pass multiple arc fillet welds made in the horizontal position shall not exceed ½ inch.

203.7.6.2. The thickness of weld layers is not limited. In making the root pass of a groove weld either single or multiple electrodes may be used. Backing bars or root faces shall be of adequate thickness to prevent melting through at the root. When the width of a surface in a groove on which a layer of weld metal is to be deposited exceeds ½ inch, multiple electrodes shall be displaced laterally or a split-layer technique used to assure adequate corner fusion. When the width of a previously deposited layer exceeds 1 inch, and two electrodes only are used, a split-layer technique with electrodes in tandem shall be employed.

203.7.6.3. The welding current, arc voltage, speed of travel and relative location of electrodes shall be such that each pass will have complete fusion with the adjacent base metal and weld metal and such that there will be no depressions or undue undercutting at the toe of the weld. Excessive concavity of initial passes shall be avoided to prevent cracking in roots of joints under restraint.

203.7.6.4. The maximum welding current in making a groove weld shall be:

1. 700 amperes for any single electrode or for any parallel electrode when making a root pass in a groove having no root opening and which does not fill the groove.
2. 750 amperes for any single electrode or 900 amperes for any parallel electrode when making a root layer in a groove having steel backing or a spacer bar.
3. 1,000 amperes for any single electrode or 1,200 amperes for any parallel electrode for all other passes.

203.7.6.5. The maximum welding current to be used in making a fillet weld shall be 1,000 amperes for any single electrode or 1,200 amperes for any parallel electrode, subject to the restrictions of paragraph 203.7.2.3.

203.7.6.6. Where required by the D.C.F.S. a sample joint having the same cross section as the joint to be used in construction and a length of at least 3 ft. shall be welded with the electrode, flux, current, arc voltage and speed of travel that are proposed to be used and a macroetched cross section of the welded joint shall be prepared as a demonstration that the requirements of Paragraphs 203.7.2.3, 203.7.2.6, 203.7.2.7, 203.7.6.2, and 203.7.6.3 of this article will be met. When welding current, arc voltage and speed of travel are established by a test made in accordance with the requirements of this paragraph, they shall be kept within the limitation of variables as given in Section IV.
203.7.6.7. Multiple arc welds may also be made in the root of groove or fillet welds using a combination of flux cored arc welding with CO₂ shielding followed by multiple submerged arcs, provided that flux cored arc welding shall conform to the requirements of Article 203.8 and provided the spacing between the CO₂ shielded arc and the first following submerged arc shall not be greater than 15 inches. The spacing between arcs shall be such that the slag cover over the weld metal produced by a leading arc does not cool sufficiently to prevent proper weld deposit of a following electrode.

203.7.6.8. Preheat and interpass temperatures for multiple electrode submerged arc welding shall be in accordance with Table 203.5. Alternately for single pass groove or fillet welds, and with the approval of the D.C.E.S. preheat and interpass temperatures may be established for combinations of materials being welded and the heat input involved, as the temperature sufficient to reduce the hardness in the heat-affected zones of the base metal to less than 225 Vickers Hardness Number for steel having a minimum specified Tensile Strength not exceeding 50,000 psi.

203.7.6.8.1. Hardness determinations of the heat-affected zones shall be made on:
(1) initial macro cross sections of a sample test specimen and
(2) the surface of the member during the progress of the work. The surface shall be ground prior to hardness testing, and testing shall be conducted under conditions that will produce valid test results in the opinion of the D.C.E.S.
(a) The frequency of such heat-affected zone testing shall be at least one test area per weldment on the thicker metal involved in a joint for each 30 ft. of groove weld or pair of fillet welds.
(b) These hardness determinations may be discontinued after the procedure has been established to the satisfaction of the D.C.E.S.

203.7.6.8.2. No reduction of the preheat requirements for Table 203.5 will be permitted for fillet welds 1/2 inch and under in size.

203.8. Requirements for Flux Cored-Arc Welding.


203.8.1.1. All welding procedures for flux cored arc welding shall be qualified in accordance with the provisions of Section IV.

203.8.1.2. The welding procedure shall always include external carbon dioxide gas shielding.

203.8.2. Electrodes.

203.8.2.1. The FCAW electrodes and carbon dioxide shielding gas for flux cored arc welding used for joining base metal with minimum specified yield points of 50,000 psi or less, shall conform to the requirements of the latest edition of the “Specification for Mild Steel Electrodes for Flux Cored Arc Welding,” AWS A5.20, Classification E70T-1.

203.8.2.2. As required by Article 203.4, the Contractor shall furnish acceptable certification that the electrode and shielding gas combination will meet the requirements of the classification or grade.

203.8.3. Shielding Gas. The gas or gas mixture used for shielding flux cored arc welding shall be of a welding grade having a dew point of -40° F or lower. The Contractor shall furnish acceptable certification that the gas or gas mixture is suitable for the intended application and will meet the dew point requirements.

203.8.4. Procedures For Flux Cored Arc Welding With Single Electrode.

203.8.4.1. Welding shall be restricted to the flat and horizontal positions.
203.8.4.2. Electrodes shall be dry and in suitable condition for use. Electrodes shall be received in containers that include a sealed plastic enclosure for the electrode to insure protection from moisture.

203.8.4.3. The maximum diameter of electrode shall be 5/32 inch.

203.8.4.4. The maximum size of a fillet weld made in one pass shall be: ½ inch for the flat position and 5/16 inch for the horizontal position.

203.8.4.5. The thickness of weld layers, except root and surface layers, shall not exceed 1/8 inch. Where the root opening of a groove weld is 1/8 inch or greater, a multiple pass, split-layer technique shall be used. The split-layer technique shall also be used in making all multiple pass welds when the width of the layer exceeds 5/8 inch.

203.8.4.6. The welding current, arc voltage, gas flow, and speed of travel shall be such that each pass will have complete fusion with adjacent base metal and weld metal and there will be no overlap or excessive porosity or undercutting.

203.8.4.7. Complete penetration groove welds made without the use of steel backing shall have the root of the initial weld air-arc gouged, chipped, or otherwise removed to sound weld metal before welding is started from the second side.

203.8.4.8. Flux cored arc welding with external gas shielding shall not be done in a draft or wind unless the weld is protected by a shelter. This shelter shall be of material and shape appropriate to reduce wind velocity in the vicinity of the weld to a maximum of five miles per hour.

203.8.4.9. Where required by the D.C.E.S., a sample joint, having the same cross section as the joint to be used in construction and a length of at least one foot, shall be welded with the electrode, shielding gas, current, arc voltage, gas flow, and speed of travel that are proposed to be used, and a macroetch cross section of the welded joint shall be prepared as a demonstration that the requirements of Par. 203.8.4.5 and 203.8.4.6 will be met. When welding current, arc voltage, speed of travel and rate of flow or shielding gas are established by a test made in accordance with the requirements of this paragraph, they shall be kept within the limitation of variables as given in Section IV.

203.9. Requirements for Electroslag Welding.

203.9.1. General.

203.9.1.1. All welding procedures for electroslag welding shall be qualified in accordance with the requirements of the D.C.E.S. The provisions of this article are for E.W. welding in compression components of bridges and for tensile and compression components in buildings.

203.9.1.2. The welding procedure shall include the joint details, filler metal type and size, amperage, voltage (type and polarity), speed of vertical travel if not an automatic function of deposition rate, oscillation (traverse speed, length and dwell time), type of flux, type of molding shoe, post heat treatment if used and other pertinent information.

203.9.2. Weld Metal Properties. The electrodes and flux when used as provided in the Procedure Specification for Electroslag Welding shall be capable of producing weld metal having the minimum mechanical properties listed below:

- Tensile Strength: 70,000 to 95,000 psi
- Yield Strength, min: 50,000
- Elongation in 2 inches, min: 22%
- Reduction in Area, Min: 40%
- Charpy V-Notch: Impact Strength, min: 15 ft-lbs at 0° F.
203.9.3. Condition of Flux. Flux used for electro slag welding shall be non-hygrosopic, dry and free of contamination from dirt, mill scale or other foreign material. All flux shall be purchased in packages capable of being stored under normal conditions for at least six months without such storage affecting its welding characteristics or weld properties. Flux from packages damaged in transit or in handling shall be discarded or shall be dried before use at a minimum temperature of 250° F for one hour. Flux that has been wet shall not be used.

203.9.4. Procedures for Electro slag Welding.

203.9.4.1. The electrodes shall be dry, clean, and in suitable condition for use.

203.9.4.2. Flux and consumable guide coating (when the process requires a consumable guide tube) shall be dry and free of contamination from dirt, mill scale, or other foreign material which may affect the quality or strength of the weld.

203.9.4.3. The type and diameter of the electrodes used shall meet the requirements of the Procedure Specification.

203.9.4.4. Welds shall be started in such a manner to permit sufficient heat build-up for complete fusion of the weld metal to the groove face of the joint. Welds stopped at any point in the length of the joint and restarted after a delay of more than one minute shall be examined for full fusion by nondestructive methods and repaired if necessary in accordance with Par. 203.9.4.6.

203.9.4.5. With the high heat input characteristic of this process, preheating is not normally required. However, no welding shall be performed when the temperature of the base metal at the point of welding is below 40° F.

203.9.4.6. Welds having defects prohibited by Art. 203.18 or 203.19 shall be repaired as permitted by Art. 203.20 utilizing a qualified welding process or the entire weld shall be removed and replaced. Since this process melts the base metal up to 1½ inches back from the original joint boundary on each side of the joint under some welding conditions in thick plate, these melt-back areas shall also be examined by nondestructive tests and repaired when necessary. When a defective joint is cut out and rewelded, it may be necessary to repair the new joint boundaries by procedures approved by the D.C.E.S. prior to rewelding unless by the rearrangement of plates, the defective melt-back areas are relocated to areas where there is no calculated stress.

203.9.4.7. All electro slag welds will be subject to nondestructive testing. The type of testing may be shown on the plans or directed by the D.C.E.S. at the time the welding procedure specification is approved if F.W. welding was not called for on the plans. The cost of RT or UT or both as required, shall be included in the unit price bid for Structural Steel.

203.10. Special requirements for A588 Steel. The following notes shall apply whenever ASTM A588 Steel is used for primary stress carrying members.

203.10.1. Flame Cut Edges. The Contractor shall take steps to assure that the flame cut edges of main material subject to tensile stresses are not hardened by the cutting process. This may be achieved by preheating, post heating or control of the burning process. Flame cut edges found to have a Rockwell Hardness Value of RC 30 or greater will be considered unacceptable. A portable Rockwell Hardness Tester will be employed by the Inspector to determine conformance with these requirements. Unacceptably hard surfaces shall be removed by grinding or machining.

203.10.2. Tack Welds. There shall be no tack welding on steel that is not preheated to the minimum specified preheat and interpass temperature required for this steel unless the tack weld and adjacent heat affected zone is completely remelted and incorporated in the subsequent semi-automatic or automatic weld. All temporary tack welds that are not remelted and incorporated into a permanent weld shall be removed by grinding. The areas where the tack welds are removed shall be magnetic particle inspected by the Contractor in accordance with Section VIII. Hardness tests of these areas may also be performed by the Inspector.
203.10.3. Minimum Heat Input. The welding procedure used shall produce the following minimum heat input values:

- For material from 3/8 inch to 3/4 inch in thickness incl. ... 35 kilojoules per in.
- Material over 3/4 inch in thickness... 50 kilojoules per in.

Heat input values shall be calculated by the Contractor for all proposed welding procedures and submitted to the D.C.E.S. for approval. (Also see provisions for minimum preheat and interpass temperatures, Article 203.5).

203.11. Joint Details.

203.11.1. Residual Stresses. Joints shall be welded so as to minimize, insofar as practical, stresses due to the contraction of the weld metal and adjacent base metal upon cooling. When weldments are subject to unusual restraint or when plate thickness becomes excessive, the Contractor may submit revised joint details to limit the size of the weld nugget and thereby reduce residual stresses and distortion caused by welding. The State will approve these weld details provided it is adequately demonstrated that there is access for welding and that the details, welding procedure and inspection methods used will insure satisfactory results in the work. Peening may be approved by the D.C.E.S. to control shrinkage stresses. All peening shall be performed in accordance with Par. 203.13.8.

203.11.2. Transition of Thicknesses or Widths.

203.11.2.1. When butt joints are used to join material of different thicknesses or widths, there shall be smooth transitions between offset surfaces or edges at a slope of not more than 1 in 2½ with the surface of either part, see Fig. 203.11.2.a and b. The transition of thickness may be accomplished by sloping weld faces, by chamfering the thicker part, or by a combination of the two methods.

203.11.2.2. Joints made between plates of different widths may be considered the same as those made in plates of equal widths, and the unit stress of the parent metal may be used, if the transition is made as shown in Fig. 203.11.2.c and the following requirements:

(a) The parts joined are of equal thickness.
(b) Weld soundness is established by radiographic testing.
(c) The weld is finished smooth and flush with the base metal as described in Par. 203.17.

203.11.3. Prohibited Types of Joints and Welds. The following types of joints and welds are prohibited in bridges:

(a) Butt joints not fully welded throughout their cross section.
(b) Groove welds made from one side only unless completely fused to a steel backing as specified in Art. 203.15.
(c) Intermittent groove welds.
(d) Intermittent fillet welds, unless otherwise specified.
(e) Bevel and J grooves for other than horizontal position welding.

NOTE: This does not prohibit the use of partial penetration tee and corner welds for bridges and building when detailed on the plans.

203.11.4. Qualification of Joints.

203.11.4.1. Joints that conform to the details specified in Par. 203.11.5 through 203.11.9 and which are welded with manual shielded metal-arc, submerged arc or flux cored arc welding in accordance with the requirements of Arts. 203.6, 203.7 and 203.8 of this manual, may be used without performing joint welding procedure qualification tests.
Transition by Sloping Weld Surface

Transition by Sloping Weld Surface and Chamfering

Chamfer before welding

Centerline Alignment
(Particularly applicable to web plates)

Offset Alignment
(Particularly applicable to flange plates)

*Groove may be of any permitted or qualified type and detail. Transition slopes shown are the maximum permitted.

Fig. 203.11.2a — Transition at Butt Joints in Parts of Unequal Thickness.

Fig. 203.11.2b — Transition of Width
Symbols for Joint Types

- B – butt joint
- C – corner joint
- T – tee joint
- BC – butt or corner joint
- TC – tee or corner joint
- BTC – butt, tee or corner joint

Symbols for Base Metal Thickness and Penetration

- L – limited thickness—complete joint penetration
- U – unlimited thickness—complete joint penetration
- P – partial joint penetration

Symbols for Weld Types

- 1 – square-groove
- 2 – single-Vee-groove
- 3 – double-Vee-groove
- 4 – single-bevel-groove
- 5 – double-bevel-groove
- 6 – single-U-groove
- 7 – double-U-groove
- 8 – single-J-groove
- 9 – double-J-groove

Symbols for Welding Processes, if not Manual Shielded Metal-arc

- S – Submerged Arc
- G – Gas Metal-Arc
- F – Flux Cored Arc

Fig. 203.11.4—Prequalified joints, method of joint and weld classification.
TABLE 203.11.4
JOINT QUALIFICATION TESTS FOR GROOVE WELDS.

<table>
<thead>
<tr>
<th>Maximum Thickness to be Welded in Construction</th>
<th>Number and Type of Tests Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Test Plate Thickness</td>
</tr>
<tr>
<td>Up to and including ( \frac{3}{8} ) in.</td>
<td>3/8 in.</td>
</tr>
<tr>
<td>Over ( \frac{3}{8} ) in.</td>
<td>1 in.</td>
</tr>
</tbody>
</table>

203.11.4.2. Joint details may depart from the details prescribed in Par. 203.11.5 through 203.11.9 only if approved by the D.C.E.S. The Contractor shall submit to the D.C.E.S. his proposed alternate joint details and joint welding procedures, and at his own expense demonstrate their adequacy by the tests described in Table 203.11.4. Welding shall conform to the applicable provisions of Arts. 203.6, 203.7 and 203.8.

203.11.5. Details of Fillet Welds.

203.11.5.1. The details of fillet welds made by manual shielded metal-arc welding; submerged arc welding; or flux cored arc welding permitted by Par. 203.11.4.1 to be used without joint welding procedure qualification are listed in the following Pars. 203.11.5.2 through 203.11.5.5 and detailed in Fig. 203.11.5.

203.11.5.2. The minimum fillet weld size, except that of fillet welds used to reinforce groove welds, shall be as shown in the following table:

TABLE 203.11.5

<table>
<thead>
<tr>
<th>Material Thickness of Thicker Part Joined, in</th>
<th>Minimum Size* of Fillet Weld, in</th>
</tr>
</thead>
<tbody>
<tr>
<td>To 3/4 incl.</td>
<td>1/4**</td>
</tr>
<tr>
<td>Over 3/4 to 1 1/2</td>
<td>5/16</td>
</tr>
<tr>
<td>Over 1 1/2 to 2 1/4</td>
<td>3/8</td>
</tr>
<tr>
<td>Over 2 1/4 to 6</td>
<td>1/2</td>
</tr>
<tr>
<td>Over 6</td>
<td>5/8</td>
</tr>
</tbody>
</table>

*Except that the weld size need not exceed the thickness of the thinner part joined.
**Not permitted for joints carrying primary stress. Use 5/16 inch.
203.11.5.3. The maximum size of fillet weld that may be used along edges of material shall be:
a. Along edges of material less than 5/16 in. thick, the maximum size may be equal to the
   thickness of the material.
b. Along edges of material 5/16 in. or more in thickness, the maximum size shall be 1/16 in.
   less than the thickness of material, unless the weld is especially designated on the drawings
to be built out to obtain full throat thickness as illustrated in Fig. 203.11.5, A or B.

203.11.5.4. The minimum length of a fillet weld shall be four times its size and in no case less than
1 1/2 inches.

203.11.5.5. Fillet welds which support a tensile force that is not parallel to the axis of the weld, or
which are proportioned to withstand repeated stress shall not terminate at corners of parts or
members but shall be returned continuously, full size around the corner for a length equal to twice
the weld size where such return can be made in the same plane. End returns shall be indicated on
design and detail drawings.

203.11.5.6. Seal welding shall preferably be accomplished by a continuous weld combining the
functions of sealing and strength. Seal welds should be detailed as fillet or groove welds on the
shop drawings.

203.11.5.7. Fillet welds may be used in skew joints that have an included angle of not less than 60
degrees. Permitted forms of such joints are detailed in Fig. 203.11.5, C and D. These joints may be
fabricated with an included angles of less than 60 degrees provided the welding procedure and
details are approved by the D.C.E.S.

203.11.6. Plug and Slot Welds.

203.11.6.1. Plug and slot welds will be permitted only when detailed on the plans or as part of an
approved repair procedure.
203.11.6.2. Plug and slot welds may be made only in the flat position unless otherwise approved as part of a repair procedure and will be subject to nondestructive tests when stated in the Contract Documents or when ordered by the D.C.E.S. in the approval of a repair procedure.

203.11.7. Complete Joint-Penetration Groove Welds Made by Manual Shielded Metal-Arc Welding.

203.11.7.1. A complete joint penetration groove weld is defined as one which has been made from both sides or from one side and fused into steel backing of a chemistry suitable for welding generally A36 Steel, having complete penetration and fusion of weld and base metal throughout the depth of the joint.

203.11.7.2. Complete joint penetration groove welds made by manual shielded metal-arc processes in butt, tee and corner joints which may be used without performing the joint welding procedure qualification tests prescribed by Par. 203.11.4.1 are detailed in Fig. 203.11.7 and are subject to the limitations specified in the following Par. 203.11.7.3.

203.11.7.3. Dimensions of groove welds specified on design or shop drawings may deviate from the dimensions shown in Fig. 203.11.7 only within the following limits:

(a) The specified thickness of material is the maximum nominal thickness that may be used.
(b) The root face of the joints is zero unless dimensioned otherwise. It may be detailed to exceed zero or the specified dimension by not more than 1/16 inch. It may not be detailed less than the specified dimension.
(c) The root opening of the joints is minimum. It may be detailed to exceed the dimension shown by not more than 1/16 inch.
(d) The groove angle is minimum. It may be detailed to exceed the dimensions shown by not more than 10 degrees.
(e) The radius of J- and U-grooves is minimum. It may be detailed to exceed the dimension shown by not more than 1/8 inch. U-grooves may be prepared prior to or after fitting.
(f) Double-groove welds may have grooves of unequal depth but the depth of the shallower groove shall not be less than one-fourth of the thickness of the thinner part joined.
### Welds Joints

<table>
<thead>
<tr>
<th>Welds Joints</th>
<th>Square-Groove Weld (1)</th>
<th>Single-Vee-Groove Weld (2)</th>
<th>Single-Bevel-Groove Weld (4)</th>
<th>Arc Gouge (AG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt Joint (B)</td>
<td>![Image of Butt Joint (B)]</td>
<td>![Image of Single-Vee-Groove Weld (2)]</td>
<td>![Image of Single-Bevel-Groove Weld (4)]</td>
<td>![Image of Arc Gouge (AG)]</td>
</tr>
<tr>
<td>Tee Joint (T) or Corner Joint (C)</td>
<td>![Image of Tee Joint (T) or Corner Joint (C)]</td>
<td>![Image of Single-Vee-Groove Weld (2)]</td>
<td>![Image of Single-Bevel-Groove Weld (4)]</td>
<td>![Image of Arc Gouge (AG)]</td>
</tr>
</tbody>
</table>

### Notes:

1. For all joints, except B-L1a and C-L1a, gouge root before welding second side as follows: All Carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/8 inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.

2. See Par. 203.11.7.3 for allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

**Fig. 203.11.7** – COMPLETE JOINT PENETRATION prequalified manual shielded metal-arc welded joints – base metal of LIMITED thickness (L).
NOTES:
1. Gouge roots of joints without backing as follows:
   Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/4 inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.
2. See Par. 203.11.7.3 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.
3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.
   * The use of these welds shall preferably be limited to base metal thickness of 5/8 in. or larger.
   ** The use of these joints is limited to the horizontal position.
   ♦ AWS joint detail modified.

Fig. 203.11.7 (CONTINUED) COMPLETE JOINT PREPARATION prequalified manual shielded metal arc welded joints – base metal of UNLIMITED thickness (C).
### WELDS

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>U-GROOVE WELD</th>
<th>J-GROOVE WELD</th>
<th>GOUGE AFTER FIT-GROOVE WELD (GAF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUTT JOINT (B)</td>
<td><strong>SINGLE U-GROOVE (6)</strong></td>
<td><strong>SINGLE J-GROOVE (8)</strong></td>
<td><strong>UNLIMITED</strong></td>
</tr>
<tr>
<td></td>
<td><strong>DOUBLE U-GROOVE (7)</strong></td>
<td><strong>DOUBLE J-GROOVE (9)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>B-U6</strong></td>
<td><strong>B-U8</strong></td>
<td><strong>B-U9</strong></td>
<td><strong>B-U9AF</strong></td>
</tr>
<tr>
<td><strong>B-U5</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TEE JOINT (T) OR CORNER JOINT (C)

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>U-GROOVE WELD</th>
<th>J-GROOVE WELD</th>
<th>GOUGE AFTER FIT-GROOVE WELD (GAF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUTT JOINT (B)</td>
<td><strong>SINGLE U-GROOVE (6)</strong></td>
<td><strong>SINGLE J-GROOVE (8)</strong></td>
<td><strong>UNLIMITED</strong></td>
</tr>
<tr>
<td></td>
<td><strong>DOUBLE U-GROOVE (7)</strong></td>
<td><strong>DOUBLE J-GROOVE (9)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>C-U6</strong></td>
<td><strong>C-U8</strong></td>
<td><strong>C-U9</strong></td>
<td><strong>C-U9AF</strong></td>
</tr>
<tr>
<td><strong>C-U5</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### LIMITATIONS FOR JOINTS

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>PERMITTED WELDING POSITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-U6, B-U7, and C-U6</td>
<td><strong>ALL POSITIONS</strong></td>
</tr>
<tr>
<td><strong>FLAT AND OVERHEAD ONLY</strong></td>
<td></td>
</tr>
</tbody>
</table>

### LIMITATIONS FOR JOINTS

<table>
<thead>
<tr>
<th>JOINTS</th>
<th>PERMITTED WELDING POSITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC-U8a, TC-U8b, TC-U9a, and TC-U9b</td>
<td><strong>ALL POSITIONS</strong></td>
</tr>
<tr>
<td><strong>FLAT AND OVERHEAD ONLY</strong></td>
<td></td>
</tr>
</tbody>
</table>

### NOTES:

1. Gouge roots of joints without backing as follows:
   - Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be \( \frac{3}{4} \) inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.

2. See Par. 203.11.7.3 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to \( \frac{1}{4} \) in. but not more than \( \frac{3}{8} \) in. \( T \) is the thickness of the groove weld.

* The use of these welds shall preferably be limited to base metal thickness of \( \frac{3}{8} \) in. or larger.

** The use of these joints in limited to the horizontal position.

***Gouge: After-Fit Groove Welds shall be prepared by butting two plates together, full thickness, with zero root opening. The joint shall then be prepared for welding by air carbon-arc gouging to one half the depth of the thinner plate. After welding the groove thus prepared, the joint shall be back gouged from the second side into sound weld metal and then welded. All grooves prepared by this method shall have a minimum radius of \( \frac{1}{4} \) inch and the sides of the groove shall slope back with a total included angle of 20 degrees.

AWS joint detail modified.

Fig. 203.11.7 (CONTINUED) COMPLETE JOINT PENETRATION prequalified manual shielded metal arc welded joints — base metal of unlimited thickness (U).
203.11.8. Complete Joint-Penetration Groove Welds Made by Submerged Arc Welding.

203.11.8.1. A complete-penetration groove weld is defined as one welded from both sides or from one side and fused into steel backing of a chemistry suitable for welding, generally A36 Steel, having complete penetration and fusion of weld and base metal throughout the depth of the joint.

203.11.8.2. Complete joint penetration groove welds made by submerged arc processes in butt, tee and corner joints which may be used without performing the joint welding procedure tests prescribed by Par. 203.11.4.1 are detailed in Fig. 203.11.8 and are subject to the limitations specified in Par. 203.11.8.3 and 203.11.8.4.

203.11.8.3. All submerged arc welding of groove welds is to be done in the flat position.

203.11.8.4. Dimensions of groove welds specified on design or shop drawings may deviate from the dimensions shown in Fig. 203.11.8 only within the following limits:

(a) The specified thickness of material is the maximum nominal thickness that may be used.
(b) The root face of the joints is maximum.
(c) The root opening of closed joints shall be detailed as zero (no deviation). The root opening of open joints with backings is minimum. It may be detailed to exceed the dimension shown by not more than 1/16 inch.
(d) The groove angle is minimum. It may be detailed to exceed the dimensions shown by not more than 10 degrees.
(e) The radius of U-grooves is minimum. It may be detailed to exceed the dimensions shown by not more than 1/8 inch. U-grooves may be prepared prior to or after fitting.
NOTES:

1. Groove roots of joints without backing as follows:
   Air carbon-arc gauge to sound weld metal before welding the second side. The minimum radius of the gauge shall be 1/8 inch. The sides of the gauge area shall slope back with a total included angle of 20 degrees minimum.

2. See Par. 203.11.8.4 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

3. Groove welds in tee and corner joints shall be reinforced with tillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

Fig. 203.11.8 — COMPLETE JOINT PENETRATION prequalified submerged arc welded joints — base metal of LIMITED (L) and UNLIMITED (U) thickness.
<table>
<thead>
<tr>
<th>Butt Joint (B)</th>
<th>Single Bevel-Groove (4)</th>
<th>Double Bevel-Groove (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEE Joint (T)</td>
<td>TC-U4a-S</td>
<td>TC-L4a-S Persistent</td>
</tr>
<tr>
<td>OR COR. Joint (C)</td>
<td>TC-U4b-S</td>
<td>TC-L4b-S Persistent</td>
</tr>
<tr>
<td>Manual shielded metal-arc or submerged arc fillet weld backing.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES:**

1. Gouge roots of joints without backing as follows:
   Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/4 inch. The sides of the gouge area shall slope back with a total included angle of 30 degrees minimum.

2. See Par. 203.11.8.4 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 3/8 in. T is the thickness of the groove weld.

Fig. 203.11.8 (CONTINUED) - COMPLETE JOINT PENETRATION prequalified submerged arc welded joints - base metal of LIMITED (L) and UNLIMITED (U) thickness.
<table>
<thead>
<tr>
<th>BUTT JOINT (B)</th>
<th>ARC GOUGE (AG)</th>
<th>GOUZE AFTER FIT (GAF)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U-GROOVE WELD</strong></td>
<td><strong>DOUBLE-U-GROOVE</strong> (7)</td>
<td><strong>U-GROOVE</strong></td>
</tr>
<tr>
<td>1/4 R</td>
<td>20°</td>
<td>2.5</td>
</tr>
<tr>
<td>1/4 R</td>
<td>20°</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>B-U7-S</strong></td>
<td><strong>B-LAG-S</strong></td>
<td><strong>B-UGAF-S</strong></td>
</tr>
</tbody>
</table>

**NOTES:**

1. Gouge roots of joints without backing as follows: Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/4 inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.

2. See Par. 203.11.8.4 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

*Gouge After-Fitting Welds shall be prepared by buttting two plates together, full thickness, with zero root opening. The joint shall then be prepared for welding by air carbon-arc gouging to one half the depth of the thinner plate. After welding the groove thus prepared, the joint shall be back gouged from the second side into sound weld metal and then welded. All grooves prepared by this method shall have a minimum radius of 1/4 inch and the sides of the groove shall slope back with a total included angle of 20 degrees minimum.

Fig. 203.11.8 (CONTINUED) – COMPLETE JOINT PENETRATION prequalified arc welded joints – base metal of LIMITED (L) and UNLIMITED (U) thickness.
203.11.9. Complete Joint Penetration Groove Welds Made by Flux Cored Arc Welding.

203.11.9.1. A complete penetration groove weld is defined as one which has been made from both sides or from one side and fused into steel backing of a chemistry suitable for welding, generally A36 Steel having complete penetration and fusion of weld and base metal throughout the depth of the joint.

203.11.9.2. Complete joint penetration groove welds made by the flux cored arc processes in butt, corner and tee joints which may be used without joint welding procedure qualification tests prescribed by Par. 203.11.4.1 are detailed in Fig. 203.11.9 and are subject to the limitations specified in the following Par. 203.11.9.3.

203.11.9.3. Dimensions of groove welds specified on design or detail drawings may deviate from the dimensions shown in Fig. 203.11.9 only within the following limits:

(a) The specified material or weld throat thickness is the maximum nominal thickness that may be used.
(b) The root face of the joints may be detailed to exceed the specified dimension by not more than 1/16 inch. It may not be detailed less than the specified dimension.
(c) The root opening of the joints is minimum. It may be detailed to exceed the dimension shown by not more than 1/16 inch.
(d) The groove angle is minimum. It may be detailed to exceed the dimension shown by not more than 10 degrees.
(e) The radius of U- and J-grooves is minimum. It may be detailed to exceed the dimension shown by not more than 1/8 inch. Preparation may be prior to or after fitting.
(f) Double groove welds may have grooves of unequal depth, but the depth of the shallower groove shall not be less than one-fourth the thickness of the thinner part joined.
### Notes:

1. For all joints without backing, gouge roots as follows: Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/4 inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.
2. See Par. 203.11.9.3 for allowable variation of dimensions and Art. 203.12 for workmanship tolerances.
3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 3/8 inch. T is the thickness of the groove weld.

AWS joint detail modified.

---

**Fig. 203.11.9** – COMPLETE JOINT PENETRATION prequalified FCAW welded joints – base metal of LIMITED (L) thickness.
<table>
<thead>
<tr>
<th>Butt Joint (B)</th>
<th>Vee-Groove Weld</th>
<th>Bevel-Groove Weld</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Vee-Groove (2)</td>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>Double Vee-Groove (3)</td>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>Single Bevel-Groove (4)</td>
<td><img src="image5" alt="Diagram" /></td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>Double Bevel-Groove (5)</td>
<td><img src="image7" alt="Diagram" /></td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**TEER Joint (T) or Cor Joint (C)**

| C-U2-F | TC-U4a-F | TC-U4b-F | *TC-U5-F |

**LIMITATIONS FOR JOINTS**

<table>
<thead>
<tr>
<th>Shielding</th>
<th>Position</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>30°</td>
<td>3/16&quot;</td>
</tr>
<tr>
<td>Shielded</td>
<td>All</td>
<td>45°</td>
</tr>
</tbody>
</table>

**NOTES:**

1. Gouge roots of joints without backing as follows: Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 1/4 inch. The sides of the gouge area shall stop back with a total included angle of 20 degrees minimum.
2. See Par. 203.11.9.3 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.
3. Groove welds in tee and corner joints shall be reinforced with fillet welds equal to T/4 but not more than 3/8 inch. T is the thickness of the groove weld.

*The use of these welds shall be limited to base metal thickness of 3/8 inch or larger.

**These joints are limited to the horizontal position.

AWS joint detail modified.

**Fig. 203.11.9** – COMPLETE JOINT PENETRATION prequalified FCAW welded joints – base metal of UNLIMITED (U) thickness.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>*B-U6-F</td>
<td>*B-U7-F</td>
<td>*B-U8-F</td>
<td>*B-U9-F</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tee Joint (T) or Cross Joint (C)</th>
<th>Single U-Groove (6)</th>
<th>Double U-Groove (7)</th>
<th>Single J-Groove (8)</th>
<th>Double J-Groove (9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-U6-F</td>
<td>TC-U8b-F</td>
<td>TC-U8d-F</td>
<td>*TC-U9b-F</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Gouge roots of joints without backing as follows: Air carbon-arc gouge to sound weld metal before welding the second side. The minimum radius of the gouge shall be 3/16 inch. The sides of the gouge area shall slope back with a total included angle of 20 degrees minimum.
2. See Par. 203.11.9.3 for all allowable variation of dimensions and Art. 203.12 for workmanship tolerances.

*The use of these welds shall be limited to base metal thickness of 5/8 inch or larger.
**These joints are limited to the horizontal position.

AWS joint detail modified.

Fig. 203.11.9 (CONTINUED) – COMPLETE JOINT PENETRATION prequalified FCAW welded joints – base metal of UNLIMITED (U) thickness.
203.12. Tolerances for Joint Preparation and Fit-up.

203.12.1. The parts to be joined by fillet welds shall be brought into as close contact as practical. The maximum gap between parts being joined shall be 3/16 inch unless a modified welding procedure is approved by the D.C.E.S. If the separation is greater than 1/16 inch, the weld size shall be increased by the amount of the separation or the Contractor shall demonstrate that the required throat thickness has been obtained.

203.12.2. The separation between faying surfaces of lap joints and of butt welds landing on a backing shall not exceed 1/16 inch.

203.12.3. Abutting parts to be joined by butt welds shall be carefully aligned. Where the parts are effectively restrained against bonding due to eccentricity in alignment, an offset not exceeding 10 percent of the thickness of the thinner part joined, but in no case more than 1/8 inch, may be permitted as a departure from the theoretical alignment. In correcting misalignment in such cases, the parts shall not be drawn in to a greater slope than 3/8 inch in 12 inches. Measurement of offset shall be based upon center line of parts unless otherwise shown on the drawing.

203.12.4. Dimensions of the cross section of groove welded joints which vary from those shown on the detail drawings by more than the following workmanship tolerances shall be referred to the D.C.E.S. for approval or correction:

<table>
<thead>
<tr>
<th>TABLE 203.12</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Root face of joint* .......................................................... ± 1/8 inch</td>
</tr>
<tr>
<td>(2) Root opening of joints without steel backing* .......................... +1/16 in., −1/8 in.</td>
</tr>
<tr>
<td>Root opening of joints with steel backing** ................................. +1/4 in., −1/16 in.</td>
</tr>
<tr>
<td>(3) Groove angle of joint* .......................................................... ±10 deg., −5 deg.</td>
</tr>
</tbody>
</table>

*Joints with roots gouged.

**Root openings wider than permitted by the above tolerances but not greater than the thickness of the thinner part may be built up by welding to acceptable dimensions prior to the joining of the parts by welding provided the procedure is approved by the D.C.E.S.

203.12.5. Grooves produced by gouging shall be in accordance with groove profile dimensions as specified in Fig. 203.11.7 through 203.11.9. The minimum radius of the gouge shall be 3/8 inch at the root.

203.12.6. Members to be welded shall be brought into correct alignment and held in position by bolts, clamps, wedges, guy lines, strutts, other suitable devices or by tack welds until welding has been completed. The use of jigs and fixtures is recommended where practicable. Suitable allowances shall be made for warpage and shrinkage. Tack welds shall meet the requirements of par. 203.10.2 and 203.16.

203.12.7. Welds shall be terminated at the ends of a joint in a manner that will ensure sound welds. Unless otherwise approved, all groove welds shall be terminated on run-off tabs. Run-off tabs shall be removed upon completion and cooling of the weld and the ends of the weld made smooth and flush with the edges or ends of the abutting parts. Run-off tabs shall have the same joint dimensions as the weld.
203.13. Control of Distortion and Shrinkage Stresses.

203.13.1. In assembling and joining parts of a structure or of built-up members and in welding reinforcing parts to members, the procedure and sequence shall be such as will minimize distortion and shrinkage stresses.

203.13.2. Insofar as practicable, all welds shall be deposited in a sequence that will balance the applied heat of welding and shrinkage stresses while the welding progresses.

203.13.3. The Contractor shall develop welding procedures which in conjunction with the overall fabrication methods will produce members and structures meeting the quality requirements of the Contract Documents. These procedures and any revisions necessary in the course of the work shall be sent for information and comment to the D.C.E.S.

203.13.4. The direction of the general progression in welding on a member shall be from points where the parts are relatively fixed in position with respect to each other toward points where they have a greater relative freedom of movement.

203.13.5. Joints expected to have significant shrinkage should usually be welded before joints expected to have lesser shrinkage and they should be welded with as little restraint as possible.

203.13.6. All shop splices in each component part of a cover-plated beam or built-up member shall be made before such component part is welded to other component parts of the member. Long girders may be made by shop splicing sub-sections each made in accordance with this paragraph.

203.13.7. In making welds under conditions of severe external shrinkage restraint, the welding shall be carried continuously to completion or to a point that will insure freedom from cracking before the joint is allowed to cool below the minimum specified preheat and interpass temperature.

203.13.8. Peening will be permitted on intermediate weld layers for control of shrinkage stresses in thick welds and to prevent cracking only after the approval of the procedure and equipment by the D.C.E.S. No peening shall be done on the root or surface layer of the weld. The peening tool used shall be rounded to a 1/4 inch minimum radius at the striking end. Care shall be taken to prevent overlapping or cracking of the weld or base material.

No procedure or equipment will be permitted that will allow moisture, oil, or other contaminants to get into the weld joint.

All peening energy shall be directed against the convex surfaces of the weld beads. No peening of base metal or the fusion boundaries will be permitted. Peening will only be permitted when the weld is between 150° F minimum and 550° F maximum.


203.14.1. Before welding over previously deposited metal all slag shall be removed and the weld and adjacent base metal shall be brushed clean. This requirement shall apply not only to successive layers but also to successive beads and to the crater area when welding is resumed after any interruption.

203.14.2. Arc strikes outside of the area of permanent welds shall be avoided on all material. Blemishes resulting from arc strikes shall be ground to a smooth contour and checked to insure soundness and freedom from unacceptable hardening of the final surface of base and weld metal. MP inspection and Rockwell Hardness Tests may be ordered by the D.C.E.S. The costs of such tests shall be borne by the Contractor.

203.15. Backing and Run-Off Tabs.

203.15.1. Run-off tabs and backings used for the welding of any of the steels permitted by Art. 203 may be of ASTM A36 Steel or of a steel with the same general chemistry as the metal being welded. Groove welds made with the use of steel backing shall have the weld metal thoroughly fused with the backing.
Steel backing shall be made continuous for the full length of the weld. All necessary joints in the steel backing shall be complete joint penetration butt welds meeting all workmanship requirements of Section II.

203.15.2. All run-off tabs and backings shall be removed after welding and the joint ground smooth. Backing may be left in place on tee and corner welds unless otherwise specified.

203.16. Temporary and Tack Welds.

203.16.1. Temporary and tack welds shall be subject to the same quality requirements as final welds except that:

(a) Preheat is not mandatory for single pass welds which are completely remelted with their attendant heat affected zones and incorporated into continuous semi-automatic or automatic welds.
(b) Defects such as undercut, unfilled craters and porosity need not be removed before the final semi-automatic or automatic welding if such welds are to be remelted.
(c) The minimum length of each tack weld shall be 1½ inches.

203.16.2. Temporary or tack welds which are not incorporated into the final weld shall be removed and the surface shall be made flush with the original surface. The areas where the welds are removed shall be magnetic particle inspected by the Contractor in accordance with Section VIII. Hardness tests of these areas may be performed by the Inspector.

Temporary or tack welds which are incorporated into final welds shall be made with electrodes meeting the physical requirements of the final weld and shall be cleaned thoroughly. Multiple pass tack welds shall have casedeced ends.

203.16.3. There shall be no temporary attachments by welding to tension areas of any structural steel unless specifically approved by the D.C.E.S. All temporary welds in tension areas, when approved, shall meet all the quality requirements of the specifications for permanent welds including preheat, interpass temperatures and minimum heat input controls. Temporary welds shall be removed as described in Par. 203.16.2.

203.16.4. For temporary and tack welding on ASTM A588 Steel the provisions of Par. 203.10.2 shall also apply.

203.17. Weld Profiles and Fillet Weld Sizes (Bridges and Buildings)

203.17.1. All fillet welds shall be of acceptable types as depicted by Fig. 203.17 A, B and C with no defects such as those shown in Fig. 203.17 D. In no case, except at the outside of a corner joint, shall the convexity exceed the value 0.1S + 0.03 in., where S is the actual size of the fillet weld in inches. (See Fig. 203.17 C.)

Fillet welds in any single continuous weld shall be permitted to underrun the nominal fillet size required by 1/16 inch without correction provided that the undersize weld does not exceed 10% of the length of the weld. On web-to-flange welds on girders, no underrun is permitted at the ends for a length equal to twice the width of the flange.

Oversize fillet welds are not considered unacceptable unless they produce excessive distortion. Corrections when necessary will be limited to correcting distortion and testing the soundness of the weld and adjacent base metal.
Desirable Fillet Weld Profiles

Acceptable Fillet Weld Profile

Defective Fillet Weld Profiles

Acceptable Butt Weld Profile

Defective Butt Weld Profile

Convexity “C” shall not exceed 0.15 ± 0.03 in.

Reinforcement “R” shall not exceed 1/8 in.

Fig. 203.17 – Illustrations of acceptable and defective weld profiles.
203.17.2. All butt welded joints subject to radiographic inspection as prescribed in Section VI shall be ground smooth four sides before being radiographed. Welds in plate 3/8 inch or less in thickness shall be ground flush. Other joints to be radiographed may be finished leaving some reinforcement provided all surface lines have been removed by grinding and reinforcement does not exceed the following:

**TABLE 203.17**

<table>
<thead>
<tr>
<th>Plate Thickness (In.)</th>
<th>Thickness of Reinforcement (In.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8 to 1</td>
<td>3/64 each side or 3/32 Total</td>
</tr>
<tr>
<td>over 1 to 2</td>
<td>1/16 each side or 1/8 Total</td>
</tr>
<tr>
<td>over 2 to 3</td>
<td>3/32 each side or 3/16 Total</td>
</tr>
<tr>
<td>over 3</td>
<td>1/8 each side or 1/4 Total</td>
</tr>
</tbody>
</table>

The finish grinding need not be parallel to the direction of stress in the joint, when the surface roughness is less than ANSI 125. The reinforcement at any joint need not be equally distributed on each side of the joint if the reinforcement does not exceed the above tabulated totals. No weld reinforcement will be permitted on the side of a joint that is a faying surface, contact surface, or exposed web surface of fascia girders.

203.17.3. All other butt welds not subject to radiographic inspection and/or grinding shall be made with a slight or minimum reinforcement and shall have no defects such as those shown in Figure 203.17.F. The height of reinforcement shall not exceed 1/8 inch on any side of a joint and shall have a gradual transition to the plane of the base metal surface. (See Fig. 203.17.E.)

203.17.4. Special care shall be taken to insure that shapes and plates are not ground below the ordered thickness. Small localized reductions in section thickness (not to exceed 10% of the length of the weld) will be permitted provided the reduction is not more than five percent of the ordered thickness of the thinner piece. General undergrinding shall not exceed 0.010 inches below the ordered thickness. Sections ground below these limits shall be rewelded and radiographed.

203.17.5. Undercut shall not be more than 0.01 inch deep when its direction is transverse to the primary stress in the part that is undercut. Undercut shall not be more than 1/32 inch deep when its direction is parallel to the primary stress in the part that is undercut.

203.17.6. Welds shall be free from overlap.
203.18. Quality of Welds — Bridges.

203.18.1. All welds shall be visually inspected. A weld subject to only visual inspection shall be acceptable if visual inspection shows that the weld has no cracks, that thorough fusion exists between weld metal and base metal and between successive passes in the weld, that all craters are filled to the full cross section of the weld, and that weld profiles conform to the requirements of these specifications.

203.18.2. The frequency of piping porosity in the surface of fillet welds shall not exceed one in four inches or six in four feet of weld length and the maximum diameter shall not exceed 3/32 inch.

Since piping porosity does not have to extend to the surface of the weld to present a serious structural defect, a subsurface inspection for porosity will be required by the Inspector whenever piping porosity 3/32 inch or larger in diameter extends to the surface at intervals of 12" or less over a distance of four feet, or when the condition of electrodes, flux, base metal or the presence of weld cracking indicates that there may be a problem with piping or gross porosity. This subsurface inspection shall be a visual inspection of 12-inch long sections of the fillet weld throat, after it has been ground or removed by arc-air gouging to a depth of 1/2 the design throat. When viewed at the mid-throat of the weld, the sum of the diameters of all porosity shall not exceed 3/8 inch in any linear inch of weld or 3/4 inch in any 12-inch length of weld.

203.18.3. Welds that are subject to non-destructive testing, other than visual inspection of the weld in process, on the surface of the completed weld or of the cross section of a milled and required by design, shall meet all of the requirements for welds visually inspected as described above and shall also conform to the standards of acceptance listed in Section VI, Radiographic Inspection or Section VII, Ultrasonic Inspection; Section VIII, Magnetic Particle Inspection; or Section IX, Dye Penetrant Inspection as provided in the Contract Documents.

203.19. Quality of Welds — Buildings.

203.19.1. All welds shall be visually inspected. A weld subject to only visual inspection shall be acceptable if visual inspection shows that the weld conforms to the requirements for welds subject to visual inspection as stated in Art. 203.18, Quality of Welds — Bridges.

203.19.2. Welds subject to radiographic inspection shall conform to the requirements of Section VI, Radiographic Inspection of Groove Welds in Butt Joints and the weld quality requirements for buildings described therein.

203.19.3. Welds subject to ultrasonic inspection shall conform to the requirements of Section VII, Ultrasonic Inspection and the Minimum Acceptance Levels for Buildings as described therein.

203.19.4. Welds subject to magnetic particle and dye penetrant inspection shall conform to the requirements of Sections VIII and IX, respectively.

203.20. Correction of Workmanship Defects.

203.20.1. A piece or member containing welding which is unsatisfactory or which indicates inferior workmanship may be corrected by measures approved by the D.C.E.S.

203.20.2. Defective or unsound welds shall be corrected either by removing and replacing the entire weld, or as follows:

(a) Overlap or excessive convexity: reduce by removal of excess weld metal by grinding.

(b) Excessive concavity of weld or crater, undersize welds, undercutting: clean and deposit additional weld metal after heating to minimum preheat temperature.

(c) Excessive weld porosity, excessive slag inclusions, incomplete fusion and overlap not correctable by grinding: remove defective portions and reweld.

(d) Cracks in weld: ascertain the extent of the crack by use of magnetic particle inspection or other equally positive means; remove the crack and sound metal 2 in. beyond each end of the crack, and weld.
203.20.3. The removal of weld metal may be done by machining, grinding, chipping or air carbon-arc gouging unless otherwise provided. The removal shall be conducted in such a manner that the remaining weld metal or base metal is not nicked or undercut. Defective portions of the weld shall be removed without substantial removal of the base metal. All air-carbon arc gouging shall be followed by grinding to remove carbon pick-up.

203.20.4. Additional weld metal to compensate for deficiency in size shall be deposited using an electrode preferably smaller than that used for making the original weld, but not less than 5/32 in. in diameter. The surfaces shall be cleaned thoroughly before welding. Minimum preheat and interpass temperatures shall be observed. Minimum welding heat input requirements shall be observed.

203.20.5. Where work performed subsequent to the making of a deficient weld has rendered the weld inaccessible or has caused new conditions which would make the correction of the deficiency dangerous or ineffectual, the original conditions shall be restored by removing welds or members or both before making the corrections, or else the deficiency shall be compensated for by additional work done according to a design revision approved by the D.C.E.S.

203.20.6. Caulking of welds shall not be permitted.

203.20.7. Written repair procedures including sketches or full size drawings as necessary to fully describe the deficiencies and the proposed repair shall be submitted to the D.C.E.S. for approval, when any of the following conditions exist:

(a) Defective base metal including lamellar tears
(b) Large number of weld defects, Par. 203.20.2 in any one member
(c) Any cold crack in weld or base metal
(d) Heat-shrink procedures are to be used to modify the as-built geometry of welded assemblies
(e) Members are to be repair welded or modified to correct fabrication errors in cutting, punching, drilling, fitting, etc.

203.20.8. The D.C.E.S. shall be advised prior to cutting apart improperly fitted and welded members.

203.21. Stress-Relief Heat Treatment.

203.21.1. Where required by the Contract Documents, welded assemblies shall be stress relieved by heat treating. Finish machining shall be done subsequent to stress relieving. The welded assembly shall be adequately supported during stress relieving. The temperature shall be maintained uniformly during heating and cooling so that the temperature throughout the assembly will differ by not more than 100°F at any time. After a mean temperature range between 1100°F and 1200°F is reached, the temperature of the assembly shall be held within the above specified limits for one hour per inch of thickness. When the assembly has cooled to 600°F it may be removed from the furnace unless cooling to a lower temperature is required to prevent distortion.

203.21.2. Alternately, when it is impractical to post-weld, heat treat to the temperature limitations stated above, welded assemblies may be stress relieved at lower temperatures for longer periods of time as follows:

<table>
<thead>
<tr>
<th>Decrease in Temperature below Minimum Specified Temperature (Degree F)</th>
<th>Minimum Holding Time at Decreased Temperature (Hours per Inch of Thickness)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>2</td>
</tr>
<tr>
<td>100</td>
<td>3</td>
</tr>
<tr>
<td>150</td>
<td>5</td>
</tr>
<tr>
<td>200</td>
<td>10</td>
</tr>
</tbody>
</table>
204. SHOP ASSEMBLY

204.1. Bolts and Bolted Connections.

204.1.1. General. Where the use of bolts is indicated in the Contract Documents, the bolts furnished shall be unfinished bolts (ordinary rough or machine bolts), turned bolts, or high strength bolts, as specified.

204.1.2. Unfinished and Turned Bolts. Unfinished bolts shall be standard bolts with hexagonal heads and nuts. The use of "button" head bolts will not be permitted. Bolts transmitting shear shall be threaded to such a length that not more than one thread will be within the grip of the metal. The bolts shall be of lengths which will extend entirely through their nuts but not more than 3/8 inch beyond them. The diameter of the bolt holes shall be 1/16 inch greater than the diameter of the bolts used.

Holes for turned bolts shall be carelu reamed or drilled and the bolts turned to a driving fit by being given a finishing cut. The threads shall be entirely outside of the holes and the heads and nuts shall be hexagonal. One-quarter inch thick washers shall be used with all turned bolts. Approved nut-locks shall be used on all turned bolts unless otherwise approved by the D.C.E.S. Washers shall be provided for all bolts passing through slotted holes. Unless otherwise noted, these washers shall completely cover the slotted holes.

204.1.3. Connections using high strength bolts. This specification covers the assembly of structural joints using ASTM Designation A325 High Strength Steel Bolts or other approved fasteners, tightened to a specified tension. The bolts shall be used in holes having a nominal diameter slightly larger than the nominal bolt size. The hole size shall not exceed the nominal bolt size by more than 1/16 inch, except as provided for by the Specifications.

204.1.3.1. Bolts, Nuts and Washers.

204.1.3.1.1. The bolts, nuts and washers used shall conform to the provisions of ASTM Designation A325 unless otherwise provided in the Contract Documents.

204.1.3.1.2. Bolt dimensions shall conform to the current requirements of the American National Standard for Heavy Hexagon Structural Bolts (ANSI B18.2.1). Bolt lengths shall provide for two flat washers on each bolt, or beveled washers as required, with a minimum stick-through of the bolt (beyond the nut) of 1/16 inch. Bolt lengths shall also be such that the nut in the fully tightened position does not encounter the thread runoff.

204.1.3.1.3. Nut dimensions shall conform to current requirements of the American National Standard for Heavy Semifinished Hexagon Nuts (ANSI B18.2.2).

204.1.3.1.4. Circular washers shall be flat and smooth and their nominal dimensions shall conform to the dimensions given in Table 204.1a.

Beveled washers for American Standard beams and channels shall be square or rectangular, shall taper in thickness, and shall conform to the dimensions given in Table 204.1a. Where necessary, washers may be clipped on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer.

204.1.3.2. Bolted Parts

204.1.3.2.1. The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material. Holes may be punched, subpunched and reamed, or drilled as required by the Contract Documents, and shall have a nominal diameter not more than 1/16 inch in excess of the nominal bolt diameter except as provided by the Specifications.
<table>
<thead>
<tr>
<th>Bolt Size No.</th>
<th>Circular Washers</th>
<th>Square or Rectangular Beveled Washers for American Standard Beams and Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal Outside Diameter</td>
<td>Nominal Diameter of Hole</td>
</tr>
<tr>
<td>1/2</td>
<td>1-1/16</td>
<td>17/32</td>
</tr>
<tr>
<td>5/8</td>
<td>1-5/16</td>
<td>21/32</td>
</tr>
<tr>
<td>3/4</td>
<td>1-15/32</td>
<td>13/16</td>
</tr>
<tr>
<td>7/8</td>
<td>1-3/4</td>
<td>15/16</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1-1/16</td>
</tr>
<tr>
<td>1-1/8</td>
<td>2-1/4</td>
<td>1-1/4</td>
</tr>
<tr>
<td>1-1/4</td>
<td>2-1/2</td>
<td>1-3/8</td>
</tr>
<tr>
<td>1-3/8</td>
<td>2-3/4</td>
<td>1-1/2</td>
</tr>
<tr>
<td>1-1/2</td>
<td>3</td>
<td>1-5/8</td>
</tr>
<tr>
<td>1-3/4</td>
<td>3-3/8</td>
<td>1-7/8</td>
</tr>
<tr>
<td>2</td>
<td>3-3/4</td>
<td>2-1/8</td>
</tr>
<tr>
<td>Over 2 to 4 incl.</td>
<td>2D - 1/2</td>
<td>D + 1/8</td>
</tr>
</tbody>
</table>

<sup>a</sup>Dimensions in inches.
<sup>b</sup>3/16 in. nominal.
<sup>c</sup>1/4 in. nominal.

204.1.3.2.2. When assembled, all joint surfaces, including those adjacent to the bolt heads, nuts or washers shall be free of scale, except tight mill scale, and shall also be free of burrs, dirt, paint and other foreign material that would prevent solid seating of the parts.

204.1.3.2.3. Contact surfaces within joints shall be free of oil, paint, lacquer or galvanizing unless otherwise specified.

204.1.3.3. Installation.

204.1.3.3.1 Bolt Tension. Each bolt shall be tightened to provide, when all bolts in the joint are tight, at least the minimum bolt tension shown in Table 204.1.b for the size of bolt used.

Bolts shall be tightened with properly calibrated wrenches or by the turn-of-nut method. If required because of bolt entering and wrench operation clearances, tightening by either procedure may be done by turning the bolt while the nut is prevented from rotating.

Impact wrenches, if used, shall be of adequate capacity and with sufficient supply of air to perform the required tightening of each bolt in approximately ten seconds.

204.1.3.3.2. Washers. Connections shall be assembled with a hardened washer under both the bolt head and nut except when interference-body bolts or similar button head fasteners are specified in the Contract Documents. When a button head fastener is specified the washer may be omitted under the head.
TABLE 204.1b – BOLT TENSION

<table>
<thead>
<tr>
<th>Bolt Size, in inches</th>
<th>Minimum Bolt Tension&lt;sup&gt;a&lt;/sup&gt; in Thousands of Pounds (Kips)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>12</td>
</tr>
<tr>
<td>5/8</td>
<td>19</td>
</tr>
<tr>
<td>3/4</td>
<td>28</td>
</tr>
<tr>
<td>7/8</td>
<td>39</td>
</tr>
<tr>
<td>1</td>
<td>51</td>
</tr>
<tr>
<td>1-1/8</td>
<td>56</td>
</tr>
<tr>
<td>1-1/4</td>
<td>71</td>
</tr>
<tr>
<td>1-3/8</td>
<td>85</td>
</tr>
<tr>
<td>1-3/2</td>
<td>103</td>
</tr>
</tbody>
</table>

<sup>a</sup>Equal to 70 percent of specified minimum tensile strengths of bolts, rounded off to the nearest Kip.

Where an outer face of the bolted parts has a slope of more than 1:20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

204.1.3.3.3. Calibrated Wrench Tightening. When calibrated wrenches are used to provide the bolt tension specified in par. 204.1.3.3.1 their setting shall be such as to induce a bolt tension 5% to 10% in excess of this 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 calibrating tension shall be noted and used in the installation of all bolts of the tested lot. The turned element shall be in tightening motion when torque is measured. 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 prescribed amount.

204.1.3.3.4. Turn-of-Nut Tightening. When the turn-of-nut method is used to provide the bolt tension specified in par. 204.1.3.3.1, there shall first be enough bolts brought to a “snug tight” condition to insure that the parts of the joint are brought into full contact with each other. Snug tight shall be defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench (approximately 150 foot lbs. for bolts 7/8 inch diameter and larger). 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 amount of nut rotation specified in Table 204.1c. During this operation there shall be no rotation of the part not turned by the wrench.

204.1.3.4. Inspection.

204.1.3.4.1. The Engineer shall determine that the requirements of Par. 204.1.3.1 through 204.1.3.3 are met in the work. When the calibrated wrench method of tightening is used, the Inspector shall witness the calibration tests prescribed in par. 204.1.3.3.3.
TABLE 204.1c

<table>
<thead>
<tr>
<th>Disposition of Outer Faces of Bolted Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both faces normal to bolt axis, or one face normal to axis and other face sloped not more than 1:20 (bevel washer not used)</td>
</tr>
<tr>
<td>Bolt length(^b) not exceeding 8 diameters or 8 inches</td>
</tr>
<tr>
<td>1/2 turn</td>
</tr>
</tbody>
</table>

\(^a\)Nut rotation is rotation relative to bolt regardless of the element (nut or bolt) being turned.
Tolerance on rotation: 30° (one-twelfth full turn) over or under.
For coarse thread heavy hex structural bolts of all sizes and length and heavy hex semifinished nuts.

\(^b\)Bolt length is measured from underside of head to extreme end of point.

204.1.3.4.2. Inspection of bolt tightness shall be performed by the following procedure.

204.1.3.4.2.1. Inspection shall be performed by the use of an inspection torque wrench provided by the Contractor.

204.1.3.4.2.2. Three bolts of the length and diameter being installed shall be placed and individually tested in a calibration device capable of indicating bolt tension. A washer shall be placed under the part being turned.

204.1.3.4.2.3. Each bolt specified in par. 204.1.3.4.2.2 shall be tightened in the calibration device to the minimum tension specified for its size as listed in Table 204.1b. The inspecting wrench shall then be applied to the tightened bolt and the torque necessary to turn the nut or head 5 degrees (approximately 1 inch at 12-inch radius) in the tightening direction shall be determined. The nut or head shall be in motion when the torque is measured. The average torque measured in the tests of each three bolts shall be taken as the “minimum job inspecting torque” to be used in the manner specified in par. 204.1.3.4.2.5. The “maximum job inspecting torque” shall be determined by multiplying the “minimum job inspecting torque” by 1.5.

204.1.3.4.2.4. All labor and equipment necessary for the inspection of the bolt tightness shall be provided by the Contractor and included in the price bid for Structural Steel. The State shall witness the bolt testing, but will not provide equipment or labor.
204.1.3.4.2.5. Bolts represented by each inspection lot described in par. 204.1.3.4.2.2 shall be inspected after installation by applying the inspecting wrench to a minimum of 10 percent of the bolts, but not less than two bolts, selected at random in each connection. The actual torque value of each inspected bolt shall be determined as the head or nut is in motion as the inspecting wrench is applied in the tightening direction. This value shall fall within the minimum and maximum values determined by par. 204.1.3.4.2.3. If any bolt is found to have a torque value below the minimum, or above the maximum job inspecting torque, all bolts in the connection shall be checked. All under-tightened bolts shall be tightened, and reinspected. All over-tightened bolts shall be loosened and the bolt and nut removed for visual inspection of the bolt and nut threads. Where there is visible thread damage or where the nut does not spin freely on the bolt stem when tightened by hand without the aid of a wrench, the bolt shall be rejected and replaced. Other A325 bolts may be retightened. Replaced and retightened bolts shall then be inspected as described above.

204.1.3.4.2.6. When approved by the D.C.E.S., devices that measure bolt tension in each installed fastener will be accepted in lieu of the inspection torque tests described herein.

204.1.3.5. Bolt Testing by Department Laboratory.

204.1.3.5.1. Field Connections.

204.1.3.5.1.1. Tests will be performed by the laboratory to insure that the bolts meet the physical and chemical requirements of the specifications. Only bolts from the following critical connections shall be submitted for testing:

- Stringer and girder splices;
- Stringer and girder direct support connections; i.e., attachment of stringers to cross girders, beams, etc.;
- All main member connections in trusses, arches, towers, bents and rigid frames.

204.1.3.5.1.2. For testing purposes, two bolts from each manufacturer's control lot to be used in the above described critical joints shall be sampled by the Engineer and submitted to the Department Laboratory for testing. A manufacturer's control lot is defined as all bolts of the same nominal length and diameter which are produced at the same time under the same production controls. The manufacturer's lot numbers shall be clearly marked on all containers. Lots received at the job site which contain less than 20 bolts shall not be sampled for testing.

204.1.3.5.2. Shop connections. Bolts for main connections as listed in Par. 204.1.3.5.1 that are to be installed at the fabrication plant shall be submitted to the Department Laboratory by the shop inspector. All provisions of Par. 204.1.3.5.1 shall apply.

204.2. Riveting. Rivets shall be heated uniformly to a light cherry red color and shall be driven while hot. The heating of the points of rivets more than the remainder will not be permitted. When ready for driving they shall be free from slag, scale and other adhering matter and when driven they shall completely fill the holes. Burned, burried or otherwise defective rivets, or rivets which throw off sparks when taken from the furnace, forge, or electric heater shall not be driven.

Loose, burned, badly formed or otherwise defective rivets shall be cut out. Caulking and re-cupping of rivet heads will not be allowed. In cutting out defective rivets, care shall be taken not to damage the adjacent metal. If necessary, the rivet shanks shall be removed by drilling. Countersinking shall be neatly done and countersunk rivets shall completely fill the holes.

Shop rivets shall be driven by direct-acting riveters where practicable. The riveting machine shall retain the pressure for a short time after the upsetting is complete.
The diameters of rivets indicated on the plans shall be understood to mean their diameters before heating. Heads of driven rivets shall be of approved shape, concentric with the shanks, true to size, full, neatly formed, free from fins and in full contact with the surface of the member. Rivet heads may have a collar around their complete circumference. The collar shall not have a width greater than 1/8 inch or height greater than 1/16 inch. "Jockey Caps," a partial collar, shall not exceed 1/16 inch in width.

No rivets shall be driven in the field. ASTM A325 bolts of the same nominal diameter will be installed whenever contract documents call for field riveting.

204.3. Riveted Members.

204.3.1. General. The several pieces forming one riveted member shall be straight or properly cambered before assembly. Pieces shall be close fitting before riveting is begun. Riveted members shall be free from twists, bends, open or misaligned joints and other defects resulting from faulty workmanship.

204.3.2. Riveted Plate Girders. Web plates of girders having no cover plates shall be detailed with the top edge of the web flush with the backs of the flange angles. Any portion of the plate projecting beyond the angles shall be chipped flush with the backs of the angles. Web plates of girders having cover plates may be 1/2 inch less in width than the distance back to back of flange angles. At web splices, the clearance between the ends of the web plates shall not exceed 3/8 inch.

End stiffeners and stiffener angles intended as supports for concentrated loads shall be milled or ground to secure a uniform even bearing against the flange angles. Intermediate stiffener angles shall fit sufficiently tight to exclude water after being painted.

Web splice plates and fillers under stiffeners shall fit within 1/4 inch at each end.

204.4. Shop Assembly of Field Bolted Connections.

204.4.1. Splices in Simply Supported Stringers and Girders. Simply supported stringers and girders of all cross sections shall be assembled in the shop in their cambered (no load) position and all holes in main material splices shall be reamed or drilled from the solid with all connecting parts assembled. This work shall be done with the full length of member assembled unless otherwise approved by the D.C.E.S. or provided by the requirements of Par. 204.4.2.

204.4.2. Main Member Connections to, or Splices in Trusses, Arches, Continuous Stringers and Girders, Towers, Bents and Rigid Frames. All structural components listed in the heading for this paragraph shall be assembled in the shop with milled ends of compression members in full bearing unless otherwise specified and then shall have their subsize holes reamed to specified size or shall have their required holes drilled from the solid with all connecting parts assembled. Assembly shall be full truss or girder assembly unless progressive truss or girder assembly, full chord assembly, progressive chord assembly or special complete structure assembly is specifically listed as an alternate in the Contract Documents, or approved by the D.C.E.S.

204.4.2.1. Full Truss or Girder Assembly. Full truss or girder assembly shall consist of assembling all members of each truss, arch rib, bent, tower face, continuous beam line, plate girder or rigid frame at one time. When stringers and girders are continuous because of their attachment to intermediate transverse structural steel supporting beams or girders regardless of cross section, these intermediate transverse beams or girders shall be part of the assembly. All main member connections shall be reamed or drilled from the solid with all connecting parts assembled.

204.4.2.2. Progressive Truss or Girder Assembly. When permitted by the Contract Documents, the fabricator may elect to use a system of progressive truss or girder assembly that is essentially the same as that described in Par. 204.4.2.1 above except that the structure shall be assembled for 150 feet minimum, beginning at one end. Previously assembled portions of the rearward end may be removed from the assembly in such a manner that there is 150 feet of assembly, or at least three panel or chord lengths in assembly at all times.
204.4.2.3. Full Chord Assembly. Full chord assembly shall consist of assembling the full length of each chord of each truss or each leg of each bent or tower with geometric angles at the joints and then reaming or drilling from the solid the field connection holes while the members are so assembled. When the Contract Documents permit this method of assembly, the Contractor shall have the option of reaming or drilling web members while assembled to the chords or reaming or drilling web members with properly located steel templates.

204.4.2.4. Progressive Chord Assembly. Progressive chord assembly may be employed at the Contractor’s option when permitted by the Contract Documents. The method of assembly shall be the same as that described for full chord assembly except that the number of pieces and minimum assembled length specified for progressive truss and girder assembly shall apply.

204.4.2.5. Special Complete Structure Assembly. Special complete structure assembly shall consist of assembling the entire structure including the floor system. This method of assembly will not be required unless specifically called for in the Contract Documents.

204.4.3. The work described in this Article is limited to shop assembly only. All girders and beams, whether simply supported or continuous are to be assembled in their cambered (no load) condition. The State will approve the elimination of shop assembly of continuous stringers and girders together with their attachments to transverse supporting beams provided the Contractor will perform exactly the same operation during field erection (i.e., ream assembled or drill from the solid) and assume all additional costs incurred by doing this work in the field. As an additional alternate, continuous stringers and girders may be assembled in the field in lieu of shop assembly and supported at their ends only during erection in lieu of being supported in their cambered position provided the Contractor will pay the additional cost of engineering and fabrication to adjust camber and design requirements including provisions for lateral stability during erection to insure that the complete assembly when reamed assembled or drilled from the solid and then connected will perform within the design stress limits provided in the original Contract Documents. Trusses may be assembled and reamed or drilled from the solid in their cambered position provided it is stated in the Contract Documents that the structure was designed for the secondary stresses that are created by assembling and reaming a fully cambered truss under the provisions of Par. 204.4.2.

204.4.4. Surfaces of metal to be in contact when assembled shall not be painted. Temporary protective coatings will be approved if completely removed before final assembly. The component parts shall be assembled, drift pinned to prevent lateral movement and firmly bolted to draw the parts into close contact before reaming or drilling is begun. Assembled parts shall be taken apart if necessary for the removal of burns and shavings produced by the reaming or drilling operation.

204.4.5. Members shall be free from twists, bends or other deformations. Pieces to be connected by rivets or bolts shall not be subject to any welding unless such welding is shown on the plans or approved by the D.C.E.S.

Careful measurements shall be taken while the pieces are in assembly and before any reaming or drilling to insure that the assembly conforms to the dimensions shown on the approved shop drawings.

204.4.6. When the Contract Documents allow reaming to a template, the templates shall be steel ¾ inch minimum in thickness with hardened steel bushings accurately positioned from the working lines marked on the piece and inscribed on the template.

Care shall be exercised so that the finished holes conform to the requirements of the Contract Documents and are aligned so as to insure the proper camber in the completed assembly.

204.4.7. The Contractor may use numerically controlled drills in lieu of reaming to a template.

204.4.8. Numerically controlled drills may be used in lieu of reaming assembled or drilling from the solid as required by Par. 204.4.2 provided the Contractor’s control and verification procedures are approved by the D.C.E.S. Approval of the procedure will not relieve the Contractor of his responsibility to provide accurately drilled holes in properly aligned pieces when assembled.
A minimum of 40% of the first one-fourth of the connections fabricated shall be shop assembled as determined by the D.C.E.S. to verify the quality of the holes, the accuracy of alignment and fit of mating pieces. Numerically controlled drilling shall not create a need for fills to produce accurate fit. If satisfactory work is verified by accurately checking the first quarter of the work drilled, shop assembly for verification may be reduced to a minimum of 10% selected at random to represent all connections that were required to be reamed assembled, or drilled from the solid.

All other connections which are drilled with numerical control equipment and are not shop assembled shall be checked for entering and fit of pieces by careful shop measurements made by the Contractor. The Contractor shall be responsible for the dimensions and fit of all pieces, whether shop assembled or not.

204.5. Shop Assembly of Field Welded Connections. The Contractor shall be responsible for the proper preparation of groove joints to be welded in the field. The joints shall be prepared and assembled in the shop to insure that proper joint alignment and fit-up is present at each joint when the correct camber is in the assembled pieces. The Contractor may, at his option, eliminate all shop assembly and joint preparation for field welding provided there is sufficient extra material at each joint to provide for machine oxygen cutting or air carbon-arc gouging of the joint preparation after assembly on the ground prior to erection at the site or assembly in the erected position under the proper conditions of support to provide for camber. All provisions of this specification concerning joint preparation, welding and inspection, shall apply. The members shall be free from twists, bends or other deformations.

204.6. Match-Marking. Connecting parts assembled in the shop for the purpose of rearing or drilling holes in field connections shall be match-marked and a diagram showing such marks, shall be furnished to the Engineer.

204.7. Assembly of Stiffeners.

204.7.1. Intermediate stiffeners and connection plates shall be snipped at the corners and welded to the web and compression flange unless otherwise detailed on the Contract Plans. When automatic welding procedures are required by the Contract Documents, the fillet welds connecting the stiffener or connection plate to the web shall be started at the end of the stiffener that is adjacent to the tension flange and progress toward the compression flange. At least 90 percent of the stiffener fillet welds shall extend to within ¼ inch of all snipped corners. The remaining percentage must start or stop within ¼ inch of the snipe. All fillet welds must have full throat and no unfilled craters at the beginning and end of the weld. Localized undercut of the stiffener at the point where the welding machine is stopped shall not require repair.

204.7.2. Intermediate stiffeners and connection plates may be cut 1/8 inch short and then assembled with the stiffener paint tight against the tension flange and the opposite end welded to the compression flange. The weld size at the compression flange shall be increased to include the gap as required by Par. 203.12.1. Stiffeners shall not be driven in place with sufficient force to distort the flange, web or stiffener.

204.7.3. Tack welds used during stiffener assembly shall begin at least 3 inches from the sniped ends of the stiffener and shall have a minimum length of 1½ inch. This provision is made to prevent the starting and stopping of weld passes on tack welds.

204.8. Bearing Assemblies. Sole plates or bearing assemblies may be tack-welded to the structural steel in the shop to facilitate shipment. The bearing assemblies shall be welded to the structural steel in the field after proper adjustments have been made to compensate for temperature and deadload deflections. Expansion bearings shall be aligned as required by subsection 307 of these specifications. The center line of sole plates or other fixed portions of bearing assemblies attached to the structural steel, shall not be offset from the center line of the bearing stiffeners or diaphragms by more than ½ the thickness of the flange at that location or the thickness of the bearing stiffener or diaphragm, whichever is the lesser amount.
205. DIMENSIONAL TOLERANCES FOR FABRICATED MEMBERS.

The provisions of this sub-section shall apply to all members independent of cross section whether straight or curved. Members heat-curved under the provisions of Section V, Heat-Curving and Cambering of Rolled Beams and Welded Plate Girders shall meet the dimensional tolerances of this sub-section.

205.1. Deviation from Detail Dimensions. Dimensions of shapes and plates shall conform to the tolerances described in ASTM Designation A6 before welding. After welding all members shall conform to the dimensional tolerances of these specifications.

Welded butt joints shall be placed not further than ½ inch from the point detailed. Intermediate stiffeners may vary ±3/8-inch maximum from the point detailed.

Flange and web distortion not within the limits of these specifications may be corrected by heat-shrink procedures when approved by the D.C.E.S.

205.2. Deviation from Detailed Length. Members with ends milled for bearing and members with faced end connection angles, may deviate from the detailed length by ±1/32-inch maximum. All other members may vary from detailed length by ±3/4-inch maximum unless otherwise approved by the D.C.E.S.

205.3. Deviation from Straightness of Welded Columns.

Lengths of 45 ft. and under:

\[ \frac{1/8 \times \text{No. of ft. of total length}}{10} \text{ but not over 3/8 inch} \]

Lengths over 45 ft.:

\[ \frac{3/8 \text{ in.} + 1/8 \text{ in.} \times \text{No. of ft. of total length} - 45}{10} \]

205.4. Deviation from Specified Camber or Straightness -- Bridges.

205.4.1. Deviation from Specified Camber or Straightness of Fabricated Members Prior to Shipment from the Shop.

205.4.1.1. Stringers, Girders, Floorbeams -- single erection pieces prior to assembly.

-0 ;

+1/4", or

\[ +1/4" \times \frac{\text{No. of ft. of test length measured as chord}}{10}, \text{ but not to exceed 3/4"}, \text{ or} \]

\[ +1/8" \times \frac{\text{No. of ft. from nearest end}}{10} \]

which ever is greater.

205.4.1.2. -- Truss Chord and Web members and Tower leg single erection pieces prior to assembly.

\[ \pm 1/8" \times \frac{\text{No. of ft. of total length}}{10}, \text{ but not to exceed 3/8"} \]
205.4.3. Arch and Rigid Frame single erection pieces prior to assembly.

\[ \pm \frac{1}{8}'' \times \frac{\text{No. of ft. of Total length}}{10}, \text{but not to exceed } \frac{3}{4}'' \text{.} \]

The above values shall be defined as the offsets from working or camber lines shown on approved shop drawings.

205.4.2. Allowable deviation from specified alignment at control points during shop assembly or controlled field assembly performed as an alternate to shop assembly. All steel required to be shop assembled for reaming, drilling from the solid or weld joint preparation shall be aligned to be within \( \pm \frac{1}{8} \)-inch from the location shown on the approved shop drawings. This tolerance shall apply to \( x \), \( y \) and \( z \) coordinates, i.e., in all three dimensions.

205.4.3. Deviation from Specified Camber of Erected Steel Bridge Superstructures.

\[ \text{No. of ft. of length from nearest support (incl. bearing or pin)} \times \frac{\pm \frac{1}{4}''}{10} \]

but not to exceed \( \frac{3}{8} \) inch in cantilever sections or \( 1 \frac{1}{2} \) inch between substructure supports.

Unless otherwise specified all measurements shall be taken when the steel work is completed and the superstructure is subject to steel deadload stresses only.

205.4.4. Unless the Contract Documents provide for a sag vertical curve in the highway or railway profile, no structural steel shall be considered acceptably fabricated and erected that can be anticipated to deflect below a chord line between supports when the additional deadload deflection shown on the plans is added algebraically to the elevations measured on the steel at the completion of erection. Elevations shall be measured before any load other than steel deadload is imposed on the structure.

205.4.5. The camber of each member shall be measured in the shop with the member lying on its side. The camber measurement shall be made in the presence of the Inspector and will be the basis for approval for shipment.

Final camber measurements will be made by the Engineer in the field after erection. At the time of this measurement, each member shall have all of the specified camber less the dead load deflection of the steel within the tolerance specified in Par. 205.4 above. When members do not conform to the requirements of this section, corrections of moderately excessive camber will be approved by the heat-shrink process.

Camber deficiencies which place the member on the same side of theoretical lines as superstructure dead load deflections are unacceptable and may only be corrected by heat-shrink procedures approved by the D.C.E.S.

205.5. Deviation of Beams and Girders from the Specified Horizontal Alignment.

\[ \pm \frac{1}{8} \text{ in.} \times \frac{\text{Total Length Between Supports (ft.)}}{10 \text{ ft.}} \]

205.6. Lateral deviation between centerline of web and centerline of flange of built-up girders at contact surface. \( \frac{3}{4} \) inch maximum.
205.7. Deviation from flatness of girder webs. Deviation from flatness of girder webs shall be determined by measuring offsets from a straight edge whose length is not less than the least dimension of any panel. The straight edge shall be placed in any position of maximum deviation on the web. Deviation from flatness of webs having a depth \( D \) and a thickness \( t \) in panels bounded by stiffeners and/or flanges whose least panel dimension is \( d \) shall not exceed the following:

Intermediate stiffeners on both sides of web —
   Intermediate girders —
      \( \frac{D}{t} \leq 150 \) - maximum deviation = \( \frac{d}{115} \)
      \( \frac{D}{t} \geq 150 \) - maximum deviation = \( \frac{d}{92} \)
   Fascia girders —
      \( \frac{D}{t} \leq 150 \) - maximum deviation = \( \frac{d}{130} \)
      \( \frac{D}{t} \geq 150 \) - maximum deviation = \( \frac{d}{105} \)

Intermediate stiffeners on one side only of web —
   Intermediate girders —
      \( \frac{D}{t} \leq 100 \) - maximum deviation = \( \frac{d}{100} \)
      \( \frac{D}{t} \geq 100 \) - maximum deviation = \( \frac{d}{67} \)
   Fascia girders —
      \( \frac{D}{t} \leq 100 \) - maximum deviation = \( \frac{d}{120} \)
      \( \frac{D}{t} \geq 100 \) - maximum deviation = \( \frac{d}{80} \)

No intermediate stiffeners —
   maximum deviation = \( \frac{D}{150} \)

The above deviations are tabulated in Appendix A of this manual.

Webs of plate girders that are shop assembled and have shrinkage distortion at the bolted end in excess of the flatness requirements specified, may be shipped to the project site for erection provided the shop assembly demonstrated that the splice material straightened the web to acceptable tolerances when less than 25 percent of the required splice bolts were installed.

205.8 Warpage and tilt of flange. Combined warpage and tilt of flange of welded beams or girders shall be determined by measuring the offset at the toe of flange from a line normal to the plane of the web through the intersection of the centerline of web with the outside surface of the flange plate. This offset shall not exceed 1/100 of the total width of flange or \( \frac{3}{8} \) inch, whichever is greater. This deviation does not apply to bearing areas at points of loading. (See Par. 205.9).

205.9. Bearing at Points of Loading. The bearing ends of bearing stiffeners shall be flush and square with the web and in intimate contact with at least 10 percent of the projected bearing stiffener area on the inner surface of the flanges. Also the offset as described in Par. 205.8 shall not exceed .040 inch at any bearing point. When milling is specified at a point of bearing, the surfaces shall be plane and true within .010 inch but the maximum gap between abutting parts may be .040 inch as above described.

205.10. Deviation from Specified Depth. The maximum deviation from specified depth for welded beams and girders, measured at the web centerline, shall be as follows:

- For depths up to 36 inches, incl. ±1/8 inch
- For depths over 36 inches to 72 inches, incl. ±3/16 inch
- For depths over 72 inches ±5/16 inch
  -3/16 inch

205.11. Fit of Intermediate Stiffeners. Where tight fit of intermediate stiffeners is specified it shall be defined as allowing a gap of up to 1/16 inch between stiffener and flange.
205.12. Deviation from Straightness of Intermediate Stiffeners. The out-of-straightness of intermediate stiffeners shall not exceed ¼ inch with due regard to any members which frame into them.

205.13. Deviation from Straightness of Bearing Stiffeners. The out-of-straightness of bearing stiffeners shall not exceed ¼ inch up to 6 feet or ½ inch over 6 feet and the actual centerline of the stiffener shall lie within the thickness of the stiffener as measured from theoretical centerline location.

205.14. Heat-Shrink Correction. Any camber or sweep modifications made to shapes or plates assembled and welded or prior to assembly, shall conform to the requirements of Section V, Heat Curving and Cambering Rolled Beams and Welded Plate Girders.

If heat-shrink procedures are used to correct distortion in butt welded joints, nondestructive tests, if required, shall be performed after such heat straightening.

206. MILL AND SHOP INSPECTION.

206.1. General. All steel to be furnished under this item shall be subject to shop inspection unless otherwise specified. Steel not furnished as stock steel under the conditions set forth herein shall be subject to mill inspection.

206.2. Stock Steel. No mill inspection will be required for stock steel. Stock steel will be accepted for miscellaneous parts not subject to stress. Stock steel will be accepted on the basis of the results of chemical and physical tests performed by the manufacturer. Certified copies of the results of chemical analysis and physical tests shall be furnished to the Inspector as required under the heading, “Sampling, Testing and Inspection” of Material Specification 715-01.

206.3. Notice of Rolling and Fabrication. The Contractor shall furnish the Inspector with two copies of the mill order and give ample notice to the Inspector of the beginning of the work at the mill and shop so that inspection may be provided. No material shall be rolled or fabricated before the Inspector has been notified where the orders have been placed.

206.4. Facilities for Inspection. The Contractor shall provide all facilities for the inspection of material and workmanship in both the mill and shop. The Inspector shall be allowed free access to all parts of the premises concerned with the work. Work done while the inspector has been refused access shall be automatically rejected.

206.5. Inspector’s Authority. The Inspector shall have the authority to reject materials and workmanship which do not conform to the requirements of the Contract Documents. Inspections shall be made of materials and workmanship before, during and after fabrication. Materials and workmanship which are inspected in process (while being fabricated) and which are found to contain defects or to have been subjected to damaging fabrication procedures shall be rejected while still in process.

The Inspector shall have the right to perform, at the expense of the State, nondestructive tests of the materials and workmanship.

Inspection at the mill and shop is intended as a means of facilitating the work and avoiding errors. It is expressly understood that it will not relieve the Contractor from any responsibility in regard to unacceptable material or workmanship and the necessity for replacing the same.

It is the Contractor’s responsibility to establish and maintain an effective Quality Control Program. Inspection by State Representatives is not a substitute for Quality Control by the Contractor.

206.6. Visual Inspection and Nondestructive Tests. Welds shall be subject to nondestructive testing as required by Articles 203.18 and 203.19 of this Manual and as stated in the Contract Documents, testing procedures shall conform to the requirements of Sections VI, VII, VIII and IX of this Manual. Welds, base metal (including castings and forgings), fasteners and other structural components shall be subjected to a thorough visual examination. Structural materials incorporating cracks, seams, inclusions, laminations or other defects discovered during visual examination shall be acceptably repaired or replaced. In general, defects in the base metal shall be repaired if and as required by ASTM Designation A6 and Art. 202.2.
The limits of all defects in welds and base metal shall be determined before a repair procedure is approved. To determine the limits of defects, the Inspector may require such nondestructive tests as radiographic inspection, ultrasonic inspection, magnetic particle, or dye penetrant inspection to be performed upon the defective piece. The cost of such tests, when required, shall be included in the unit price bid for the steel.

206.7. Photographs and Drawings. When defects are discovered under the provisions of Art. 206.6 and material is rejected, the Engineer may require photographs and dimensioned drawings to accompany the repair procedure submitted by the Contractor to aid in the evaluation of the repair procedure. The same provision shall apply to any structural steel rejected for workmanship deficiencies, failure to meet dimensional tolerances, or damage due to rough handling or accident. In addition, the State may require photographs of specific work or assembly conditions during shop fabrication that are a proper part of the permanent job record.

When the D.C.F.S. requests photographs of any portion of the shop fabrication the Contractor may furnish the photographs at no additional cost to the State or allow the State to take the photographs. The Contractor shall have the right to direct the taking of photographs so that only the work is recorded and so that no procedure or equipment that is the private development (industrial secret) of the fabricator is revealed.

206.8. Cost of Testing. The Contractor shall furnish all labor, materials and equipment necessary to perform chemical and physical tests on stock steel when such tests are required. Nondestructive tests shall be performed at the Contractor’s expense, if required by the provisions of Art. 206.6 above.

206.9. Inspector’s Mark of Acceptance for Shipment. When the structural steel is ready for shipment from the shop and is properly loaded on the rail cars, trucks, or barges, the Inspector representing the State shall affix the acceptance stamp of his company. This acceptance mark shall be made by paint or ink stamp or shall be an initial or initials applied with paint stick. The mark shall be placed near the erection mark on the piece and the Inspector’s steel die stamp shall be applied over the paint or ink impression.

Each shipment piece, bundle, keg, box or bound pallet shall be acceptance-marked by the Inspector by direct marking on the piece as described above or by acceptance-marking on durable tags when the material is boxed or bundled.

Application of the Inspector’s acceptance stamp implies that at the time of shipment from the shop it was the opinion of the Inspector that the structural steel was fabricated from accepted materials by approved processes, painted and loaded for shipment in accordance with the requirements of the Contract Documents.

Application of the Inspector’s stamp of approval for shipment does not imply that the structural steel will not be rejected by the State if subsequently found to be defective as described in Article 206.5 and 206.10.

206.10. Rejection. The Inspector shall reject all material and workmanship that does not conform to the requirements of the Contract Documents.

Acceptance of structural steel by State representatives at the mill, shop or in the field shall in no way preclude further testing, and inspection if there is reason to believe the material or workmanship does not conform to the requirements of the Contract Documents.

Defective materials and workmanship wherever discovered shall be rejected and then repaired or replaced at no cost to the State. All repair procedures are subject to the approval of the D.C.F.S.

206.11. Marking and Shipping. Erection pieces with computed weights exceeding three tons shall have the lifting weight to the nearest one-half ton marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packaged separately. Pins, small parts, and small packages of bolts, rivets, washers and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 300 pounds. A list and description of the contained material shall be plainly marked on the outside of each shipping container.

The weight of all tools and erection material shall be kept separate.
Anchor bolts, washers, and other anchorage or grillage materials, shall be shipped to suit the requirements of the masonry construction.

The loading, transportation, unloading and piling of structural material shall be conducted so that the metal will be kept clean and free from injury by rough handling.

Structural members shall be suitably supported and braced so that they will not be subjected to stresses in excess of those provided for in the design.

All members, both straight and curved, shall be shipped and stored with their webs vertical unless otherwise approved by the D.C.E.S. When there is doubt about the intensity of stress induced by procedures used to handle, transport or store fabricated members, the D.C.E.S. may require that the Contractor submit his support procedure for approval prior to loading and shipment. Transportation stress calculations shall include an increase of at least 100 percent for dynamic loading.

206.12. Report of Shipment of Structural Material (Form B and GC 4b). The acceptance document for all material subject to shop inspection is the Report of Shipment of Structural Material (Form B and GC 4b). When the steel is shipped from the shop to the project or to off-shop storage, the Inspector shall complete and sign Form B and GC 4b to cover all materials subject to his inspection. This document shall indicate to the Engineer that the structural steel, if not damaged by shipment, storage, erection, or subsequently found to be defective in workmanship or materials, may be paid for under the rules for payment or partial payment established by the Department.

Form B and GC 4b does not tabulate shipment weights for payment. (See Section 616.5, Structural Steel, Basis of Payment.)

206.13. Shipment of Rejected Material or Material Not Offered for Shop Inspection. When the Contract Documents indicate that materials and fabrication will be subject to shop inspection, no materials will be accepted at the project that do not bear the Inspector's mark of acceptance.

If it is determined that materials are not acceptance-marked because they were not offered for shop inspection, or shipped after rejection at the shop, the materials shall be returned to the shop for inspection and correction as necessary.

In lieu of this requirement, the State may, at its discretion, allow inspection (see Articles 206.3 through 206.10) to be performed at the project site. This work will be performed by the shop inspector or other representatives of his company and all costs for this inspection in the field shall be borne by the Contractor as a condition of the State's approval of inspection of rejected material in the field.

207. PROTECTIVE COATING AND STORAGE.

207.1. Painting. All structural steel shall receive protective coatings as specified in the Contract Documents. All metal not embedded in concrete shall, unless otherwise indicated on the Contract Drawings (Plans) or in the specifications, be painted three coats of paint in accordance with Section 635 of the Specifications.

Members or parts thereof which are embedded or in contact with cast or pneumatically projected concrete shall not be painted.

207.2. Weld Cleaning. Slag shall be cleaned from all welds. Welded joints shall not be painted until after the work has been completed and accepted. The surfaces to be painted shall be cleaned of spatter, rust, loose scale, oil, dirt, fluke deposits and any other substance that might interfere with proper painting.

All welds shall be brush striped with one coat of approved shop paint prior to general shop painting.

Welds that are to be galvanized shall be blast cleaned or otherwise treated to remove slag and any other material that will interfere with proper galvanizing.
207.3. Anchor Bolts. All anchor bolts, including pipe sleeves where required, shall be galvanized in accordance with the requirements of Material Specification 719-01, "Galvanized Coatings and Repair Methods," unless otherwise specified.

207.4. Protective Coating for Machined Surfaces. Machine-finished sliding surfaces in contact (pits, pin holes, sliding surfaces including those in sockets, as at the top of rocker bearings, etc.) shall receive one coat of any common fibrous automotive grease, as soon as machining is complete. Bronze plates in sliding contact shall also be coated with grease. The Contractor shall maintain all protective coatings to prevent corrosion. All protective coatings applied in the shop shall be removed immediately prior to assembly of the members in the field. When the protective coating is removed, the members shall be thoroughly cleaned and then coated with automotive grease before assembly. All other machine-finished surfaces shall be given one coat of the specified shop paint.

207.5. Storage of Materials. Structural material shall be stored above the surface of the ground upon platforms, skids, or other supports, and shall be protected as far as practicable from surface deterioration by exposure to conditions producing rust and shall be kept free from accumulations of dirt, oil, or other foreign matter.

Any defects created by storage at the shop shall be corrected by the Fabricator prior to acceptance for shipment by the Inspector. All fabricated material stored by the Contractor will be subject to inspection by the Engineer and any corrective action required as the result of storage shall be performed by the Contractor. All costs resulting from storage of structural material shall be borne by the Contractor.

208. STUD WELDING

208.1. Scope. This section contains provisions for the installation and inspection of steel studs welded to steel, to connect members and connection devices to concrete (as concrete anchors and as shear connectors in composite steel-concrete construction), and to fasten other members and appurtenances.

208.2. General Requirements.

208.2.1. Studs shall be of a design suitable for arc welding to steel members with automatically timed stud welding equipment. The type, size or diameter, and length of stud shall be as specified by the drawings, specifications, or special provisions as approved by the Engineer. (See Fig. 208.2.1 for dimensions and tolerances of standard type shear connectors.)

208.2.2. An arc shield (fourel) of heat-resistant ceramic or other suitable material shall be furnished with each stud.

208.2.3. A suitable deoxidizing and arc-stabilizing flux for welding shall be furnished with each stud of 5/16 inch diameter or larger. Studs less than 5/16 inch in diameter may be furnished with or without flux.

208.2.4. Finish shall be produced by cold heading, cold rolling, or machining. Finished studs shall be of uniform quality and condition, free of injurious laps, fins, seams, cracks, twists, bends, or other injurious defects. A stud with cracks or bursts deeper than one-half of the distance from the periphery of the head to the shank may be cause for rejection.

208.3. Material Requirements. Studs shall be furnished in accordance with the materials subsection 709.05 of the Standard Specifications.

208.4. Workmanship.

208.4.1. Studs shall be welded to steel members with automatically timed stud welding equipment connected to a suitable power source.

208.4.2. If two or more stud welding guns are to be operated from the same power source, they shall be interlocked so that only one gun can operate at a time, and so that the power source has fully recovered from making one weld before another weld is started.
208.4.3. While in operation, the welding gun shall be held in position without movement until the weld metal has solidified.

208.4.4. At the time of welding, the studs shall be free from rust, rust pits, scale, oil or other deleterious matter that would adversely affect the welding operation.

208.4.5. The stud base shall not be painted, galvanized, or cadmium plated prior to welding.

208.4.6. The areas on the member to which the studs are to be welded shall be free of scale, rust, dirt, paint, grease, or other injurious material to the extent necessary to obtain satisfactory welds. These areas may be cleaned by wire brushing, peening, prick-punching, or grinding.

208.4.7. Welding shall not be done when the base metal temperature is below zero degrees F., or when the surface is wet or exposed to falling rain or snow.

208.4.8. Longitudinal and lateral spacings of stud shear connectors with respect to each other and to edges of beam or girder flanges may vary a maximum of 1 inch from the location shown on the drawings, provided the adjacent studs are not closer than 2½ inches center to center. The minimum distance from the edge of a stud base to the edge of a flange shall be the diameter of the stud plus 1/8 inch, but preferably not less than 1½ inches. The accuracy of location of other types of studs shall be such as to permit a workmanlike assembly of attachments without alterations or reaming.

208.4.9. After welding, arc shields shall be broken free from shear connectors and anchor studs and, where practicable, from all other studs.

208.4.10. The studs, after welding, shall be free from any defect or substance that would interfere with their intended function.

208.5. Quality Control.

208.5.1. The first two stud shear connectors welded on each member, after being allowed to cool, shall be tested by bending to an angle of 30 degrees from its original axis by striking the stud with a hammer. If failure occurs in the weld zone of either stud, the procedure shall be corrected and two more studs shall be welded to the member and tested. If either of the second two studs fail, additional welding shall be continued on separate plates until two consecutive studs are tested and found to be satisfactory. Two consecutive studs shall then be welded to the member, tested and found to be satisfactory before any more production studs are welded to the member.

208.5.2. For members having less than 20 stud shear connectors, the stud welding procedure may be tested at the start of each day's production welding period in lieu of testing in accordance with 208.5.1. Each welding unit before use in production welding shall be used to weld two stud shear connectors to separate test material in the same general position (flat, vertical, overhead, sloping) and of similar thickness. After being allowed to cool, they shall be bent as described above. If failure occurs, the procedure shall be corrected and two consecutive studs shall be welded to the test material, tested and found to be satisfactory before any production studs are welded to the member.

208.5.3. The foregoing testing shall be performed after any change in the welding procedure.

208.5.4. If failure occurs in the stud shank, an investigation shall be made to ascertain and correct the cause before more studs are welded.

208.5.5. Studs on which a full 360 degree weld fillet is not obtained shall be replaced or at the option of the stud welding contractor, be repaired by adding a 5/16 inch weld on all sides of the missing weld fillet. All welding shall be performed using 5/32 inch diameter E7018 electrodes. All welding procedures and preheat requirements shall be as described in this Manual. The minimum length of repair weld shall be 3/8 inch beyond the defective area on each end of the defect being repaired. The repair weld shall be fused at all boundaries, have full throat throughout its length and all craters shall be filled.
208.5.6. If the reduction in the length of the studs as they are welded becomes less than normal, i.e., the length of stud is more than 1/16 inch greater than specified, welding shall be stopped immediately and not resumed until the cause has been corrected.

208.5.7. The areas of all components subjected to tensile stresses where a defective stud has been removed shall be made smooth and flush. Where in such areas base metal has been pulled out in the course of stud removal, a shielded metal-arc welding process with low-hydrogen electrodes in accordance with the requirements of this Manual, shall be used to fill the pockets and the weld surface ground flush. In compression areas of members, the repair provisions shall be the same as for tensile areas except that, when the depth of defect is not more than the lesser of 1/8 inch or 7% of the base metal thickness, the defect may be filled by grinding in lieu of filling the defective area with weld metal. Where a replacement stud is to be placed in the defective area, the above repair shall be made prior to welding the replacement stud. Replacement shear connector studs shall be tested by bending to an angle of 15 degrees from their original axis. The areas of components exposed to view in completed structures shall be made smooth and flush where a stud has been removed.

208.6. Inspection Requirements.

208.6.1. All studs subject to weld repairs in accordance with Par. 208.5.5 and all studs in which the reduction in length due to welding is less than normal shall be struck with a two-pound hammer and bent to an angle of 15 degrees from its original axis. For studs which have been repaired the direction of bending shall be opposite to the repair weld fillet. Studs that crack either in the weld, the base metal, or the shank under inspection or subsequent straightening (see Par. 208.6.4) shall be replaced.

208.6.2. At least one stud in every 100 shall be struck with a two-pound hammer and bent to an angle of 15 degrees from its original axis; or, if threaded, the stud shall be torque-tested with a calibrated torque wrench to the value shown in the Table in Fig. 208.6.2 for the diameter and thread of the stud, in a device similar to that shown in Fig. 208.6.2. If the stud fails, two more of the existing studs shall be bent or torque tested. If either of these two studs fails, all of the studs represented by the tests shall be torque-tested, bend-tested, or rejected.

208.6.3. The Engineer or the Inspector, where conditions warrant, may select a reasonable number of additional studs to be subjected to the tests specified in 208.6.1 and 208.6.2.

208.6.4. The bent stud shear connectors and concrete anchors that show no sign of failure shall be acceptable for use and left in the bent position if no portion of the stud is less than 1 inch from a proposed concrete surface. All required bending and straightening shall be done without heating before completion of the stud welding operation on the job, except as otherwise provided in the contract.

208.6.5. If, during the progress of the work, inspection and testing indicate, in the judgment of the Engineer, that the stud welds being produced are not in accordance with this Manual, the contractor will be required at his expense to make changes (such as welding procedure, welding equipment, and stud base) necessary to secure satisfactory results on studs to be subsequently welded.
Fig. 208.6.2 – Torque testing arrangement and table of testing torques.

Fig. 208.2.1 – Dimensions and tolerances, standard type shear connectors.
SECTION III

ERECTION

301. FIELD INSPECTION. All work of erection shall be subject to the inspection of the Engineer who shall be given all facilities required for a thorough inspection of the work. Materials and workmanship subject to shop inspection will be identified as acceptable for erection by the acceptance stamp of the Shop Inspector (see Art. 206.9). Materials and workmanship not required to be shop inspected will be inspected by the Engineer. Certified copies of the results of tests conducted by the manufacturer shall be furnished to the Engineer in accordance with the requirements of Material Specification 715-01, Structural Steel.

302. METHODS AND EQUIPMENT. All portions of the proposed structural steel erection procedure, including changes in loading or modifications to existing structures, shall be described on shop drawings and submitted to the D.C.E.S. for approval. These shop drawings shall meet all provisions for shop drawings stated in Article 102.

Before starting the erection of any structural steel the Contractor shall inform the Regional Director of Transportation of any portion of the erection procedure which affects the maintenance of traffic or modifies the existing pavement.

No erection work shall begin prior to the approval of the erection procedure by the D.C.E.S. and approval of the traffic maintenance procedure by the Regional Director of Transportation. These approvals shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment used, or for the responsibility of carrying out the work in accordance with the requirements of the Contract Documents.

303. HANDLING AND STORING MATERIALS. All materials shall be handled and stored in a manner approved by the Engineer and consistent with the requirements of this manual. No structural material shall, at any time, be dropped, thrown or dragged upon the ground. Structural material shall be kept clean, properly drained and stored on proper supports above ground. Girders and beams shall be placed with their webs vertical and shall be adequately shored, braced and/or clamped to resist any lateral forces which might occur during storage, handling or erection.

Long members such as columns and chords shall be supported at a sufficient number of intermediate locations to insure that there is no damage from deflection. Permanent distortion caused by handling or storage will be cause for rejection of damaged materials.

When the Contract Documents and approved shop drawings call for structural material to be painted or given any other protective coating, the Shop Inspector’s mark of acceptance on the member is intended to indicate that the paint or other protective coating was acceptable when the material was loaded for shipment. If, because of prolonged storage, delays in final field painting schedules, or for any other reason, the shop-applied protective coating deteriorates to the point where it is unacceptable, the Contractor shall restore the original protective coating to an acceptable condition at no additional cost to the State before continuing with field painting or other field coatings.

If surfaces which are to be connected by field bolting or that are subject to field welding become rusted or contaminated with any foreign material that would make these connecting procedures unacceptable, the Contractor shall restore these surfaces at no additional cost to the State by scraping, grinding or wire brushing as necessary to remove all foreign material and rust that will interfere with welding and bolting.

304. FALSEWORK. All trusses shall be erected on falsework unless otherwise permitted, in writing, by the D.C.E.S. The falsework shall be properly designed, constructed, and maintained for the loads which will be imposed upon it. The Contractor shall prepare and submit to the D.C.E.S. for approval, plans for the falsework that he will use during the erection of the steel. Approval of the Contractor’s falsework plans shall not be considered as relieving the Contractor of any responsibility.

305. SETTING ANCHOR BOLTS FOR BRIDGE BEARINGS. Anchor bolts for bridge bearings shall be set in accordance with the specified alignment, elevation and details on the Contract Drawings. When the bolts are set in masonry, templates or other suitable means shall be used to support and hold the bolts in position during concrete placement.
If pipe sleeves are specified on the plans, the construction procedure shall be as follows:

When the pipe sleeves are set they shall be filled with sand and sealed at the top with bituminous material. The pipe sleeve shall remain sealed until the bearing is ready to be set at which time the Contractor shall clean out the pipe sleeve and with the bearing anchors in its final position shall fill the sleeve to within one inch of the top of the masonry with grout consisting of one part Type 2 cement, 701-01 and two parts Mortar Sand, 703-03 mixed to a creamy consistency.

If the Contractor elects to drill the finished and cured concrete to set anchor bolts, they shall be set and grouted immediately after the holes are drilled. The Contractor shall be responsible for positioning the reinforcing steel in the bridge seat or pedestals to prevent damage to the steel reinforcement during drilling operations. The construction procedure for drilling and grouting anchor bolt holes shall be as follows:

After drilling and cleaning the holes, the bolts shall be placed in the dry holes to check proper fit and alignment. The bolts shall be removed from the holes and a cement mortar consisting of one part 701-01, Type 2 Cement and two parts 703-03, Mortar Sand, shall be mixed to a creamy consistency, and placed in the hole until the hole is approximately two-thirds full. The bolts shall then be inserted in the holes and by a uniform, even pressure or by light blows with a hammer, the bolts shall be forced down until the anchor bolt nut rests firmly against the metal shoe or pedestal. Mortar shall be added or excess mortar removed, as required to fill the hole to the top.

Other grouting procedures, such as the use of an epoxy grout, may be substituted for the cement mortar, if the materials and construction procedures are approved by the D.C.E.S. Approval of alternate materials and procedures shall not be a basis for additional charges to the State.

The location of the anchor bolts in relation to slotted holes in expansion bearings shall be determined by the prevailing temperature. The nuts on anchor bolts at the expansion ends of spans shall permit the free movement of the movable portion of the expansion bearing.

306. PREPARATION OF BEARING AREA. All structural steel to be supported upon a masonry substructure shall have a full and uniform bearing upon the substructure masonry. Structural steel bearing plates or bases shall not be placed upon masonry bearing areas which are improperly finished, deformed or irregular.

All recesses around masonry bearing areas shall be properly drained as approved by the Engineer.

All devices which support structural steel shall be permanently located to correct alignment and elevation and shall be properly finished.

Unless otherwise provided, all structural steel which will bear upon masonry shall be placed on layers of canvas and dull orange primer, a 1/8-inch thick lead sheet, or a bearing pad in accordance with Subsection 728, "Vertical Load Transmitting Devices," as specified.

All vertical load transmitting devices shall be the same size as the bearing or masonry plate it is to support. The holes to accommodate the anchor bolts shall be cleanly and accurately prepared before the material is placed.

307. EXPANSION BEARINGS. The axes of bearings shall be substantially vertical under deadload at an ambient air temperature of 45°F. To achieve this alignment, each bearing shall be accurately set when the steel superstructure is erected. The procedure used for setting the bearings shall take into account any significant difference in temperature and load between the conditions prevailing at the time of setting and the design conditions specified in the Contract Documents. The axes of the bearings shall be checked by the Engineer-in-Charge when the structure is ready for acceptance. If the axes of the bearings are found to be tilted in excess of the following limits, the Contractor shall adjust the bearings by procedures that are approved by the D.C.E.S. prior to the final acceptance of the structure.
For rocker and segmental roller bearings with a height of 12 inches or less, the maximum variation from perfect alignment, taking into account the effect of temperature and load at the time of measurement shall be calculated by the following formula:

$$M = \pm \left( \frac{L}{14,000} \right)$$

*M = Maximum Variation from Perfect Alignment
(measured as the horizontal distance between the centerline of the cap plate and the centerline of the masonry plate)

Such variations shall not exceed 1 inch offset or a 5° rotation of the moveable portion of the bearings from the required alignment, whichever is less.

The total expansion length is the distance between the centerline of the moveable bearings being considered and the centerline of the fixed bearing from which motion must progress.

The bearing height is the distance between the upper and lower contact surfaces of the moveable portion of the bearing.

The maximum variation of all other bearings of this type, having a height exceeding 12 inches, shall be considered and approved on an individual basis by the D.C.E.S.

For sliding bearings, the maximum variation from perfect alignment between the centerline of the fixed and moveable portions of the bearing device, taking into account the effect of temperature and load at the time of measurement, shall be plus or minus 1 inch provided the moveable portion of the bearing device is fully supported by the fixed portion under all temperature and loading conditions.

If the Contractor is required to adjust the expansion bearings, he may generally do so under the full dead load of the structure following approval of the procedure he proposes to use by the D.C.E.S. He will be required to correct only those bearing devices which are misaligned in excess of the tolerances described herein.

308. STRAIGHTENING BENT STEEL AND CORRECTING CAMBER DEFICIENCIES. All bent structural steel and members containing camber deficiencies shall be straightened or corrected by the proper application of heat in accordance with Section V.

Materials other than steel may be heated only with the permission of the D.C.E.S. Upon completion of straightening or camber corrections, the metal surface shall be carefully inspected for the presence of cracks or other signs of distress. All members requiring straightening or camber corrections shall be considered rejected material until the correction has been completed and accepted. The method of repair proposed by the Contractor shall be submitted on a standard shop drawing for approval of the D.C.E.S. prior to beginning the work. Approval, when granted, shall not relieve the Contractor of his responsibility for the successful completion of the work.

309. ALIGNMENT. Before field bolting or field welding, the structure shall be adjusted to correct grade and alignment and the elevations of panel points (ends of floor beams) properly regulated. Assembly tolerances shall be as described in Subsection 205. Falsework erected to support trusses during assembly shall support the trusses with the accuracy specified in Par. 205.4.2.

310. ASSEMBLING AND BOLTING. Unless erection by the cantilever method is approved, truss spans shall be erected on falsework placed to give the trusses proper camber and alignment. The falsework shall be left in place until all connections are bolted and accepted by the Engineer unless otherwise provided in the Erection Procedure submitted by the Contractor and approved by the D.C.E.S.

Splices and field connections shall have a minimum of one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins or all bolts will be permitted) before the external support systems are removed and connections riveted or bolted unless otherwise specified. Splices and connections carrying traffic during erection will be subject to the approval of the D.C.E.S.
Fitting-up bolts shall be the same nominal diameter as the rivets or final bolts and cylindrical erection pins shall be 1/32 inch larger.

Railings shall not be bolted or welded until the falsework has been removed.

311. ERECTION AND ASSEMBLY OF MEMBERS. The field assembly of component parts of a structure by bolting or welding shall involve the use of proper lifting and handling devices and temporary fixtures to erect, align and hold in place, until properly connected, all structural steel without causing distress to the members.

No member that is deformed or damaged during erection shall be accepted for payment until appropriate repairs are made using procedures approved by the D.C.F.S. prior to the start of corrective work or the member is replaced with approved material.

312. FIELD REAMING AND DRIFTING OF HOLES. Members shall be subject to only light drifting to align holes. Any members subjected to drifting that results in distortion of the member or elongation of the holes will be rejected.

Members to be reamed assembled, reamed to a template, or drilled with numerically controlled drills as indicated in the Contract Documents or on the approved Shop Drawings, shall not be field reamed without approval of the D.C.F.S. Secondary stress carrying members which have holes punched full-size in accordance with the provisions of the Contract Documents or which are connected to members with holes punched full-size, may be subjected to limited field reaming.

Reaming of secondary stress carrying members shall not elongate holes or permit an offset between plies by an amount greater than 1/16 inch for 75% of the holes in any erection sub-assembly and 1/8 inch for the remaining 25% of the holes in the erection sub-assembly (i.e., diaphragm, lateral brace, etc.).

The D.C.F.S. may approve additional reaming of secondary members provided adequate edge distances and fastener spacings are maintained when the next larger size fastener is used. The edge distances shall be considered the same for either a rolled or planed edge.

Field reaming producing results exceeding the limits previously described, will be cause for rejection of the member.

313. ADJUSTMENT OF PIN NUTS. All nuts on pins shall be properly tightened and locked as specified on the plans, and the pins so located in the holes that the members shall take full and even bearing upon them.

314. REMOVAL OF RUST AND STAINS FROM CONCRETE. All rust and other stains shall be removed from concrete surfaces in accordance with the requirements of Sub-section 601-3.08A, “Finishing Surfaces Exposed to View.” This requirement shall apply for cleaning all new concrete as well as for cleaning all existing concrete stained or damaged by the Contractor’s operations. If the Contractor elects to reduce concrete staining and rusting of surfaces which must be cleaned, he may, at no additional cost to the State, spray unpainted portions of steel members with an approximately one mil thick coat of commercial lacquer that has been given a slight coloration that will denote its presence. This lacquer coating may remain on all surfaces which are to be imbedded in or are to be in contact with concrete. The lacquer must be removed from all contact surfaces of bolted connections, from within three inches of a welded joint, and from areas which will subsequently be covered by field painting.
SECTION IV
WELDING QUALIFICATION TESTS

401. WELDING PROCEDURE QUALIFICATION

401.1. General

401.1.1. The procedures for manual shielded metal-arc welding shall be considered prequalified and are exempt from procedure qualification tests when the procedure is in accordance with the provisions of Subsection 203. Any variation in the specification requirements shall require approval of the D.C.F.S.

401.1.2. Approval of the procedures for submerged arc welding (SAW) or flux-cored arc welding (FCAW) shall be considered on an individual basis. The procedure will be approved based upon:

(a) Satisfactory completion of a Modified Procedure Qualification Test (see Fig. 401.4d) in conformance with Art. 401.2 through 401.5; and,
(b) The electrode and flux or gas combination is in accordance with those approved for use by the Department; and,
(c) The parameters agree with the current New York State Approved Welding Procedures within the limitation of variables, Art. 401.6.

401.1.3. If upon application for approval of the electrode and flux or gas combination, it is found that the Department has no record of acceptable qualification tests within the last three years or the test data furnished by the Contractor is considered unacceptable, the Full Procedure Qualification Test (see Fig. 401.4e) shall be completed in accordance with Art. 401.2 through 401.5.

401.1.4. Other Procedures. Approval of procedures or processes other than those governed by Art. 401.1 through 401.1.3 will be granted upon satisfactory completion of a Full Procedure Qualification Test in accordance with Art. 401.2 through 401.5 and other tests as may be required by the D.C.F.S.

401.2. Base Metal and Its Preparation

401.2.1. The base metal and its preparation for welding shall comply with the welding procedure. For all types of welded joints the length of the weld and the dimensions of the base metal shall be in accordance with the test plates called for herein.

401.2.2. Qualification of a welding procedure established with a base metal included in Art. 203.2 having a minimum specified yield point of 50,000 psi or less shall qualify the procedure for welding any other base metal or combination of base metals included in Art. 203.2 having a minimum specified yield point equal to or less than that of the base metal used in the test.

401.2.3. When ASTM A242 or A588 Steel is used and corrosion resistant properties are specified, the individual procedure qualification including chemical analysis will be approved by the D.C.F.S.

401.3. Position of Test WELDS. All test welds shall be made in the flat position (1G) as defined in Par. 402.7.4.

401.4. Types of Tests and Purposes. The types of specimens outlined below are to determine the mechanical properties and degree of soundness of welded joints made under a given procedure specification. The tests used are as follows:

(a) Reduced — Section tension test (for tensile strength), see Fig. 401.4(a).
(b) Side bend test (for soundness) see Fig. 401.4(b).
(c) All weld metal test (for mechanical properties), see Fig. 401.4(c).
(d) Impact test (for toughness), see ASTM A370.

401.5. Testing of Specimens by the State. All specimens except the impact block shall be submitted to the D.C.F.S. machine as shown herein. The impact block shown in Fig. 401.4(e) shall be furnished full size (6 inches by 18 inches minimum) and the specimens shall be machined by the State. All testing will be done at no cost to the Contractor.
401.6. Limitation of Variables.

401.6.1. When submitting reports for approval of procedure qualification, the Contractor shall include specific values for all applicable variables in the Weld Procedure Qualification Record, Fig. 401.6, and in par. 401.6.2.

401.6.2. The changes set forth in paragraphs 401.6.2.1 and 401.6.2.2 shall be considered essential changes in a welding procedure and shall require establishing a new procedure by qualification. When a combination of welding processes is used, the variables applicable to each process shall apply.

401.6.2.1. Submerged Arc Welding.

(a) A change in electrode and flux combination.
(b) A change in the filler metal strength level.
(c) A change in electrode diameter when using an alloy flux.
(d) A change in the number of electrodes used; i.e., single electrode to multiple electrode or vice versa.
(e) A change in the type of current (AC or DC) or polarity.
(f) A change of more than 10% above or below the specified mean amperage for each size electrode used.
(g) A change of more than 7% above or below the specified mean arc voltage for each size electrode used.
(h) A change of more than 15% above or below the specified mean travel speed.
(i) A change of more than ±10% or 1/8 inch, whichever is greater, in the longitudinal spacing of the arc.
(j) A change of more than ±10% in the angular rotation of any parallel electrode.
(k) A change in the angle of electrodes in manual or automatic welding of more than:
   (1) ±3% in the direction of travel
   (2) ±5% normal to the direction of travel
(l) For a specified welding groove, a change of more than ±25% in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes in proportion to the increased area.
(m) An increase in the diameter of the electrode used, over that called for in the procedure specification.

401.6.2.2. Flux Cored Arc Welding With External Shielding Gas.

(a) A change in electrode and method of shielding.
(b) A change in the filler metal strength level.
(c) An increase in the diameter of electrode used over that called for in the procedure specification.
(d) A change in the number of electrodes used; i.e., single electrode to multiple electrode or vice versa.
(e) A change from a single gas to any other single gas or to a mixture of gases or a change in specified percentage composition of gas mixture.
(f) A change of more than 10% above or below the specified mean amperage for each size electrode used.
(g) A change of more than 7% above or below the specified mean arc voltage for each size electrode used.
(h) A change of more than 10% above or below the specified mean travel speed.
(i) An increase of 25% or more or a decrease of 10% or more in the rate of flow of shielding gas or mixture.
(j) For a specified welding groove, a change of more than ±25% in the specified number of passes. If the area of the groove is increased, it is also permissible to increase the number of passes, in proportion to the increased area.
(k) A change in type of welding current (AC or DC), polarity or mode of metal transfer across arc.
### Tabulation of Positions of Groove Welds

<table>
<thead>
<tr>
<th>POSITION</th>
<th>DIAGRAM REF.</th>
<th>INCLINA OF AXIS</th>
<th>ROTATION OF FACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>A</td>
<td>0° to 15°</td>
<td>160° to 210°</td>
</tr>
<tr>
<td>Horizontal</td>
<td>B</td>
<td>0° to 15°</td>
<td>80° to 180°</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>280° to 360°</td>
</tr>
<tr>
<td>Overhead</td>
<td>C</td>
<td>0° to 80°</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>D</td>
<td>15° to 80°</td>
<td>80° to 280°</td>
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<tr>
<td></td>
<td>E</td>
<td>80° to 90°</td>
<td>0° to 360°</td>
</tr>
</tbody>
</table>

### Tabulation of Positions of Fillet Welds

<table>
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<tr>
<th>POSITION</th>
<th>DIAGRAM REF.</th>
<th>INCLINA OF AXIS</th>
<th>ROTATION OF FACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>A</td>
<td>0° to 15°</td>
<td>160° to 210°</td>
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<tr>
<td>Horizontal</td>
<td>B</td>
<td>0° to 15°</td>
<td>125° to 150°</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>235° to 360°</td>
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<tr>
<td>Overhead</td>
<td>C</td>
<td>0° to 80°</td>
<td></td>
</tr>
<tr>
<td>Vertical</td>
<td>D</td>
<td>15° to 80°</td>
<td>125° to 235°</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>80° to 90°</td>
<td>0° to 360°</td>
</tr>
</tbody>
</table>

(A) Positions of Groove Welds

(B) Positions of Fillet Welds

**NOTE:** The horizontal reference plane is taken to be always below the weld under consideration.

Inclination of axis is measured from the horizontal reference plane toward the vertical.

Angle of rotation of face is measured from a line perpendicular to the axis of the weld and lying in a vertical plane containing this axis. The reference position (0°) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0°) when looking at point P.

Fig. 401.3a and b. – Positions of Groove and Fillet Welds.
NOTE: Test plates must remain in these positions until welding is complete.

Fig. 401.3.1. — Positions of test plates for groove welds.
Fig. 401.4 (a) — Reduced section tension specimen

Fig. 401.4 b — Face, Root and Side Bend Specimens.
NOTES:
1. The reduced section may have a gradual taper from the ends toward the center with the ends not more than 0.005 inch larger in diameter than the center.
2. Specimen taken from the center of a weld made in 1" to 1½" plates welded with 70°F. preheat and 300°F. (±23°F) interpass temperature.

Fig. 401.4c — Standard Round All Weld Metal Tension Specimen.
NOTES:
1. The type of steel used in this test shall be approved by the D.C.V.S.
2. Minimum preheat shall be 70°F. and the minimum interpass temperature shall be 300°F. (±25°F).
3. Welding and machining shall be witnessed by a State representative.
4. Test specimens and the procedure qualification data sheet showing all parameters used for the test shall be submitted to the State for testing and review.

Fig. 401.4d — Modified Procedure Qualification Test Plate.
### NOTES:

1. The type of steel used in this test shall be approved by the D.C.E.S.
2. Minimum preheat shall be 70°F, and the minimum interpass temperature shall be 300°F (±25°F).
3. Welding and machining shall be witnessed by a State representative.
4. Test specimens and the procedure qualification data sheet showing all parameters used for the test shall be submitted to the State for testing and review.

Fig. 401.4e — Full Procedure Qualification Test Plate.
<table>
<thead>
<tr>
<th>SPECIMEN</th>
<th>TFST RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Weld Metal Tension (AWMT)</td>
<td>Tensile Strength</td>
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<tr>
<td>Side Bend</td>
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</tr>
<tr>
<td>Reduced Section Tension</td>
<td>1</td>
</tr>
<tr>
<td>Charpy Impact</td>
<td>Average Values</td>
</tr>
<tr>
<td>Weld Metal:</td>
<td>Ft. Lbs. @ 0° F.</td>
</tr>
<tr>
<td>HAZ:</td>
<td>Ft. Lbs. @ ___° F.</td>
</tr>
</tbody>
</table>

REMARKS:

Witnessed By:

Fig. 401.6—Weld Procedure Qualification Record
402. WELDER QUALIFICATION

402.1. Tests Required

402.1.1. The qualification tests described herein are specially devised tests to determine the welder's ability to produce sound welds. It is not intended that the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the approved welding procedure.

402.1.2. The qualification tests for manual and semi-automatic welders shall be as follows:

402.1.2.1. Limited thickness (SMAW & FCAW) -- The test plate shall be as shown in Fig. 402a or b (T = 3/8 in.). This test will qualify the welder for groove welds in material not over 3/8 in. in thickness and for fillet welds in unlimited thickness in the positions indicated in Table 402 qualified by the weld test position.

402.1.2.2. Unlimited Thickness (SMAW & FCAW) -- The test plate shall be as shown in Fig. 402a or b (T = 1 in.). This test will qualify the welder for groove and fillet welds in material of unlimited thickness in the positions indicated in Table 402 qualified by the weld test position.

402.1.2.3. Fillet Welds. The test plate shall be as shown in Fig. 402c. This test will qualify the welder for fillet welds in material of unlimited thickness in the positions indicated in Table 402.

402.1.2.4. Semi-Automatic (SAW). The test plate shall be as shown in Fig. 402d. This test will qualify the welder for groove and fillet welds in material of unlimited thickness in the flat position.

402.2. Base Metal. The base metal used shall comply with Art. 203.2 or the Approved Welding Procedure.

402.3. Welding Procedure

402.3.1. All manual shielded metal-arc welding qualifications shall be performed using 5/32 inch diameter electrodes conforming to the requirements of the latest edition of “Specifications for Mild Steel Covered Arc Welding Electrodes” (AWS A5.1), classification E7018 only.

402.3.2. Qualification of processes other than manual shielded metal arc shall follow the procedure specified by the Approved Welding Procedure.

402.4. Preparation of Test Specimens

402.4.1. All welding of the test plate shall be witnessed by a representative of the State.

402.4.2. At the completion of welding, the State representative shall die stamp the test plate number and identify the witnessing agency; i.e., D.O.T. – Region No.; or Testing Agency under contract to the State.

402.4.3. The weld reinforcement shall be ground flush with the surface of the test plate. Machining may be used to remove excess weld metal but the final surface must be produced by grinding. Either fiber disk or carborundum wheels will produce acceptable grinding results. No surface depressions (lines, gouges, nicks, etc.) may remain.

402.4.4. Test plates reduced in thickness by more than 1/16 inch during the grinding process will be rejected as unfit for testing.

402.5. Method of Testing Specimens

Option 1: The test specimens shall be submitted to the Department of Transportation, Bureau of Materials for radiographic testing in accordance with Section VI.
Option 2: The Contractor may radiograph the test specimen providing all testing is witnessed by a representative of a Testing Agency under contract to the State, and providing all testing is in accordance with Section VI.

402.6. Test Results. The entire weld shall be radiographed, however, 1 inch at each edge of the 5-inch plate shall be disregarded by the interpreter of the radiograph to allow for starting and stopping of the weld. For acceptable qualification, the weld as revealed by the radiograph shall conform to the requirements of Art. 203.18 Quality of Welds.

402.7. Limitation of Variables. For the qualification of a welder the following rules shall apply:

402.7.1. Qualification established with any one of the steels permitted by Art. 203.2 shall be considered as qualification to weld or tack weld any other steels.

402.7.2. A welder shall be qualified for each process used.

402.7.3. A welder qualified with an approved electrode and shielding medium combination shall be considered qualified to weld or tack weld with any other approved electrode and shielding medium combination for the process used in the qualification test.

402.7.4. Position of Test Welds. All welds that will be encountered in actual construction shall be classified as being (1) Flat, (2) Horizontal, (3) Vertical, or (4) Overhead, in accordance with the definition of welding positions given in Fig. 402.7a. Each procedure shall be tested in the manner stated below for each position for which it is to be qualified.

402.7.4.1. Groove Welds. A change in the position in which welding is done as defined below for groove welds shall require requalification. Test plates shall be welded in the following positions (illustrated in Fig. 402.7b):

(a) Flat Position (1G). The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side.
(b) Horizontal Position (2G). The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal.
(c) Vertical Position (3G). The test plates shall be placed in an approximately vertical plane with the welding groove approximately vertical.
(d) Overhead Position (4G). The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the under side.

402.7.4.2. Fillet Welds. A change in the position in which welding is done as defined below for fillet welds shall require requalification. Test plates shall be welded in the following positions (illustrated in Fig. 402.7c):

(a) Flat Position (1F). The test plates shall be so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical.
(b) Horizontal Position (2F). The test plates shall be so placed that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface.
(c) Vertical Position (3F). Each fillet weld shall be made vertically.
(d) Overhead Position (4F). The test plates shall be so placed that each fillet weld is deposited on the under side of the horizontal surface and against the vertical surface.

402.7.5. The qualification test shall be performed within the limitation of variables as listed in Art. 401.6.
402.8. Retests. In case a welder fails to meet the requirements of one or more test welds a retest may be allowed under the following conditions:

(a) A retest may be made within 30 days which shall consist of two test welds of each type on which he failed, all test specimens of which shall meet all the requirements specified for such welds.
(b) A retest may be made provided there is evidence that the welder has had additional training or practice. In this case only one test plate shall be made.

402.9. Period of Effectiveness. The welder qualification tests herein specified shall be considered as remaining in effect for three (3) years unless:

(1) the welder is not engaged in a given process of welding for which he is qualified for a period exceeding six months, or unless
(2) there is some specific reason to question a welder’s ability.

In case (1) above the requalification test need be made only in the 3/8-inch thickness.

402.10. Records. Records of the test results shall be kept by the testing agency, or Contractor and shall be available to those authorized to examine them.
NOTES:

1. All plate surfaces within the area of the backing strip must be free of mill scale and surface depressions. This includes the top and bottom of the test plates and the backing strip.

2. After welding, the weld reinforcement shall be ground flush with the surface of the plate. Do not remove the backing strip.

3. See Table 402 for type and position limitations.

4. $T = 3/8$ inch qualifies for limited thickness welding. $T = 1$ inch qualifies for unlimited thickness welding.

Fig. 402a — Welder qualification test plate for manual shielded metal-arc and semi-automatic flux cored arc welding.
NOTE:
1. \( T = 3/8 \) inch qualifies for limited thickness welding.
   \( T = 1 \) inch qualifies for unlimited thickness welding.

Fig. 402b — Optional horizontal position welder qualification test plate for manual shielded metal-arc and semi-automatic flux cored arc welding.
NOTES:

1. All plate surfaces within the area of the backing strip must be free of mill scale and surface depressions. This includes the top and bottom of the test plate and the backing strip.

2. After welding, the weld reinforcement shall be ground flush with the surface of the plate. Do not remove the backing strip.

3. See Table 402 for type and position limitations.

Fig. 402c – Fillet welder qualification test plate.
NOTES:

1. All plate surfaces within the area of the backing strip must be free of mill scale and surface depressions. This includes the top and bottom of the test plates and the backing strip.

2. After welding, the weld reinforcement shall be ground flush with the surface of the plate. Do not remove the backing strip.

3. For flat position and material of unlimited thickness.

Fig. 402d – Welder qualification test plate for semi-automatic submerged arc welding.
### TABLE 402 — Welder Qualification — Type and Position Limitations

<table>
<thead>
<tr>
<th>TEST POSITION</th>
<th>POSITION &amp; TYPE WELD QUALIFIED</th>
<th>FILLET WELD ONLY TEST***</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLAT</td>
<td>FLAT GROOVE; FLAT &amp; HORIZONTAL FILLET</td>
<td>FLAT FILLET</td>
</tr>
<tr>
<td>HORIZONTAL</td>
<td>FLAT &amp; HORIZONTAL GROOVE; F &amp; H FILLET</td>
<td>FLAT &amp; HORIZONTAL FILLET</td>
</tr>
<tr>
<td>VERTICAL</td>
<td>F, H &amp; V GROOVE; F, H &amp; V FILLET</td>
<td>F, H &amp; V FILLET</td>
</tr>
<tr>
<td>OVERHEAD</td>
<td>F &amp; OH GROOVE; F, H &amp; OH FILLET</td>
<td>F, H &amp; OH FILLET</td>
</tr>
</tbody>
</table>

*Qualifies for welding groove and fillet welds on material of unlimited thickness. (See Fig. 402a & b)

**Qualifies for welding groove welds in material not over 3/8 inch thick and fillet welds on material of unlimited thickness. (See Fig. 402a & b)

***Qualifies for welding fillet welds only, on material of unlimited thickness. (See Fig. 402c)
403. WELDING OPERATOR QUALIFICATION

403.1. Tests Required.

403.1.1. The qualification tests described herein are specially devised tests to determine the ability of an operator of a machine or automatic welding equipment to produce sound welds. It is not intended that the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the Approved Welding Procedure.
403.1.2. The test plate shall be as shown in Fig. 403. This test will qualify the welding operator for groove and fillet welding in materials of unlimited thickness.

403.1.3. The welding operator performing a successful procedure qualification as described in Par. 403.1.1 shall be considered as meeting the requirements for qualification for that process and test position in material of unlimited thickness.

403.2. Base Metal. The base metal used shall comply with Art. 203.2 or the Approved Welding Procedure.

403.3. Welding Procedure. The operator shall follow the welding procedure specified by the Approved Welding Procedure.

403.4. Test Specimens — Preparation. The inspection and preparation of test specimens shall be in accordance with Art. 402.4.

403.5. Method of Testing Specimens. The method of testing specimens shall be in accordance with Art. 402.5.

403.6. Test Results. The entire weld shall be radiographed. However, 1½ inches at each edge of the plate shall be disregarded by the interpreter of the radiograph to allow for starting and stopping of the weld.

For acceptable qualification, the weld, as revealed in the radiograph, shall conform to the requirements of Art. 203.18, Quality of Welds.

403.7. Limitation of Variables. For the qualification of a welding operator the following rules shall apply:

403.7.1. Qualification established with any one of the steels permitted by these Specifications shall be considered as qualification to weld any of the other steels.

403.7.2. A welding operator qualified with an approved electrode and shielding medium combination shall be considered qualified to weld with any other approved electrode and shielding medium combination for the process used in the qualification test.

403.7.3. A welding operator qualified to weld with multiple electrodes shall be qualified to weld with a single electrode, but not vice versa.

403.7.4. A change in the position in which welding is done as defined in Par. 402.7.4 shall require requalification.

403.7.5. The qualification test shall be performed within the limitation of variables as listed in Art. 401.6.

403.8. Retests. In case an operator fails to meet the requirements of one or more test welds a retest may be allowed under the following conditions:

(a) A retest may be made within 30 days which shall consist of two test welds of each type on which he failed, all of which shall meet all the requirements specified for such welds.

(b) A retest may be made provided there is evidence that the operator has had additional training or practice. In this case only one test plate shall be made.

403.9. Period of Effectiveness. The operator qualification tests herein specified shall be considered as remaining in effect for 3 years unless:

(1) The operator is not engaged in the given process of welding for which he is qualified for a period exceeding six months; or unless,

(2) There is some specific reason to question the operator's ability.

403.10. Records. Records of the test results shall be kept by the testing agency or Contractor and shall be available to those authorized to examine them.
NOTES:
1. All plate surfaces within the area of the backing strip must be free of mill scale and surface depressions. This includes the top and bottom of the test plates and the backing strip.
2. After welding, the weld reinforcement shall be ground flush with the surface of the plate. Do not remove the backing strip.
3. For flat position and material of unlimited thickness.

Fig. 403 – Automatic welding operator qualification test plate for submerged arc and flux cored arc welding.
404. TACKER QUALIFICATION

404.1. Tests Required.

404.1.1. The qualification tests described herein are specially devised tests to determine the tacker's ability to produce sound welds. It is not intended that the qualification tests shall be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the Procedure Qualification.

404.1.2. A tacker shall be qualified by one test plate made in each position in which he is to tack.

404.1.3. The tacker shall make a ½ inch maximum size tack weld approximately 2 inches long on the fillet-weld-break specimen as shown in Fig. 404.1 using a 5/32 inch diameter electrode.

404.2. Base Metal. The base metal used shall comply with Art. 203.2 or the Approved Welding Procedure.

404.3. Welding Procedure. The welder shall follow the procedure specified by the Approved Welding Procedure.

404.4. Preparation of Test Specimens. All welding of the test plate shall be witnessed by a representative of the State.

404.5. Method of Testing Specimens. A force shall be applied to the specimen as shown in Fig. 404.5 until rupture occurs. The force may be applied by any convenient means. The surface of the weld and of the fracture shall be examined visually for defects by a representative of the State.

404.6. Test Results Required.

404.6.1. The tack weld shall present a reasonably uniform appearance and shall be free of overlap, cracks and excessive undercut. There shall be no porosity visible on the surface of the tack weld.

404.6.2. The fractured surface of the tack weld shall show complete penetration into the root of the joint and shall exhibit no incomplete fusion to the base metal nor any inclusion or porosity larger than 3/32 inch in greatest dimension.

404.6.3. A tacker who passes the fillet-weld-break test shall be eligible to tack weld all types of joints for the process and in the positions in which he has qualified.
404.7. Limitation of Variables. For the qualification of a tacker the following rules shall apply.

404.7.1. Qualification established with any one of the steels permitted by these Specifications shall be considered as qualification to tack weld any of the other steels.

404.7.2. A tacker qualifying for manual shielded metal-arc welding shall use only 5/32 inch diameter electrodes meeting the requirements of "Specification for Mild Steel Covered Arc Welding Electrodes" (AWS A5.1), Classification E7018 only.

404.7.3. A tacker qualified with an approved electrode and shielding medium combination for a process other than manual shielded metal-arc shall be considered qualified to tack with any other approved electrode and shielding medium combination for the process used in the qualification test.

404.7.4. A tacker shall be qualified for each process used.

404.7.5. A change in the position in which tacking is done as defined in par. 402.7.4 shall require requalification.

404.8. Retests.

404.8.1. In case of failure to pass the above test, the tacker may make one retest without additional training.

404.8.2. If a tacker fails the first retest, he will be required to show evidence of additional training or practice prior to performing a further retest.

404.9. Period of Effectiveness. A tacker who passes the above test shall be considered eligible to perform tack welding for three years in the positions and with the processes for which he is qualified unless there is some specific reason to question his ability. In such case, the tacker shall be required to demonstrate his ability to make sound tack welds by again passing the prescribed tack welding test.

404.10. Records. Records of the test results shall be kept by the testing agency or Contractor and shall be available to those authorized to examine them.
SECTION V
HEAT-CURVING AND CAMBERING OF ROLLED BEAMS
AND WELDED PLATE GIRDERS

501. HEAT-CURVING ROLLED BEAMS AND WELDED PLATE GIRDERS. When the plans call for stringers and girders to be furnished with a specified horizontal curvature, the rolled beams and welded plate girders which form these pieces may be fabricated using heat-curving procedures which conform to the following requirements:

501.1. Scope. This specification pertains to rolled beams and welded I-section plate girders heat-curved to obtain the required horizontal curvature. Steel that are manufactured to a specified minimum yield point greater than 50,000 psi shall not be heat-curved without the written approval of the D.C.E.S.

Members required to be fabricated to a radius shorter than the minimum radius of curvature stated in the specification shall be fabricated as welded plate girders with the flanges flame cut to the required radius prior to assembly to the web.

501.2. Minimum Radius of Curvature. This specification will permit the heat-curving of beams and girders when the horizontal radius of curvature measured to the centerline of the member web will not be less than 150 feet, and will not be less than the larger of the values calculated (at any and all cross sections throughout the length of the member) from the following two equations:

\[
R = \frac{14}{b} \frac{D}{\psi} \sqrt{F_Y} \\
R = \frac{7500}{b} \frac{b}{F_Y} \psi
\]

In these equations, \(F_Y\) is the specified minimum yield point in ksi of the steel in the member web, \(\psi\) is the ratio of the total cross-sectional area to the cross-sectional area of both flanges, \(b\) is the widest flange width in inches, \(D\) is the clear distance between flanges in inches, \(t\) is the web thickness in inches, and \(R\) is the radius in inches.

In addition to the above requirements, the radius shall not be less than 1000 feet when flange thickness exceeds 3 inches or \(b\) exceeds 30 inches.

501.3. Camber Increase for Dead Load Deflection Caused by Residual Stresses. To compensate for possible loss of camber of heat-curved girders (camber losses of this nature are also known to occur in straight beams and girders but to a lesser degree) in service as residual stresses dissipate, the amount of camber in inches at the point of maximum deflection shall be increased by the amount shown in the following formula:

\[
* \Delta_{\text{increase}} = \frac{0.02L^2F_Y}{E y_o}
\]

Distribute \(\Delta\) increase from the point of maximum deflection as a parabola. This distribution shall be between dead-load points of contraflexure.

\(E\) is the modulus of elasticity in ksi, \(F_Y\) is the specified minimum yield point in ksi of the girder flange, \(y_o\) is the distance from the neutral axis of the steel member to the extreme outer fiber in inches (maximum distance for nonsymmetrical sections), and \(L\) is the span length or distance between points of dead-load contraflexure in inches.

Fifty percent of this camber increase shall be included in the bridge profile because camber loss will not be complete until after several months of service. The remaining fifty percent of the camber increase shall be included in the anticipated steel dead-load deflection. This shall include all steel deflection prior to composite action between the steel superstructure members and any attached concrete designed to act as a composite section. See Par. 501.13 for web cutting procedures to be followed for heat-curved welded plate girders.

*Any camber increase indicated by the formula shall be approved by the D.C.E.S. who may multiply the formula result by a factor of 0.5 to 0.95 based upon experience with long term deflections.
501.4. Preparation for Heat-Curving. Members which will be heat-curved may be completely fabricated and ready for shop painting at the time heat is applied, or the fabricator may at his option delay the welding of intermediate stiffeners and connection plates to flanges until the heat-curving has been completed.

Unless provisions are made for girder shrinkage, gusset plates and end bearing stiffeners shall be attached after the girders are heat-curved. When longitudinal stiffeners are required, they shall be heat-curved or flame cut to the required radius before being welded to the curved girder.

501.5. Physical Location of Members. This specification provides for the heat curving of structural steel members in the fabricator's plant. Stringers and girders conforming to the requirements of Par. 501.4 above may be shipped as straight members complete with or without the required shop coat of paint and then heat-curved at the bridge site if the Contractor will agree to pay the cost of field inspection of the heat-curving process and all necessary costs for field cleaning and painting.

501.6. Support of Members for Heating. Members may be heat-curved with the web in either the vertical or horizontal position. When curved with the web in the vertical position, the member must be braced or supported in such manner that the tendency of the member to deflect laterally during the heat-curving process will not cause the member to overturn. When the member is heat-curved while the web is in the horizontal position, the member must be supported at its ends and intermediate points as required to produce a uniform curvature in the member and compressive stresses in the upward projecting flange legs throughout the full length of the piece being curved.

When a member is to be laid upon its side or loaded in any way to induce stress prior to heating, the method of supporting or loading shall be described on a sketch sheet and submitted to the D.C.E.S. with copies of the design computations. The method of support and computations shall be approved prior to beginning the work.

Preheating compressive stresses will be permitted up to a maximum of 20,000 psi. This stress limit will apply to all steel covered by this specification. Any method of handling, supporting, or loading that causes the member to distort permanently (yield without the application of heat) will result in rejection of the member.

All nondestructive tests to evaluate damage prior to reacceptance and any corrective work ordered by the State to compensate for overstressing shall be performed by the Contractor at no cost to the State.

When the member is positioned horizontally for heating, intermediate safety catch blocks must be maintained at mid-distance between supports of the member and within 7 inches of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

501.7. Heating Process and Equipment. Heating shall be done using large, approximately 1 inch diameter, multi-orifice (rosebud) heating torches operating on approximately 25 psi propane and 125 psi oxygen. The torches and tips to be used will be subject to the approval of the D.C.E.S. Selection will be made to promote heating efficiency and prevent unnecessary distortion.

Heating shall be confined to the patterns described herein and shall be conducted so as to bring the steel within the planned pattern to a temperature between 1,000 and 1,100 degrees F. as rapidly as possible without overheating the steel.

Any heating procedure which causes a portion of the steel to be heated to a temperature greater than 1,200 degrees F. shall be considered destructive heating. Destructive heating shall automatically cause the rejection of the steel. Steel rejected for destructive heating may be investigated for reacceptance, repair, or replacement by tests ordered by the D.C.E.S. The cost of such tests and any necessary repair or replacement shall be borne by the Contractor.

501.8. Heating Patterns and Method of Heating. Only truncated triangular heating patterns shall be used. The base of the triangle shall be the flange edge that will be concave after curving. The apex of the heating triangle shall be truncated to provide a 1-inch width. The truncated end of the heating triangle shall be located as follows:

(a.) When the curvature required is represented by a radius 1,000 feet or less, the truncated end of the heating triangle shall be located 1/8 of the flange width but not more than 3 inches beyond the intersection of the web and flange measured from the concave flange edge.
When the curvature required is represented by a radius greater than 1,000 feet, the heating pattern may be as described in (a) above or may at the fabricator’s option be modified to locate the truncated end of the heating triangle at the junction of web and flange.

The above statements refer to the heating patterns which are to be marked on the outside flange surfaces prior to heating. Heat shall be applied to the outside surface of both the top and bottom flange at essentially the same point in the member and the heating torches shall not begin to progress towards the base of the heating pattern until the truncated end of the pattern is brought up to the specified temperature. Once heating begins to progress towards the base at the pattern, the heating torches shall not be returned to the apex of the heating triangle.

When flange thicknesses exceed 1¼ inches, heat shall be applied simultaneously to both the top and bottom surface of the flange at each heat pattern.

After beginning at the truncated end of the heating pattern on the outside flange surface, heating shall progress slowly towards the base of the pattern spreading with an included angle of 15 to 30 degrees. The base of the heating triangle shall not exceed 10 inches regardless of flange width and thickness.

When flange thicknesses are such that both surfaces of the flange must be heated simultaneously, heat shall not be applied to the inside flange surface until the heat being applied to the outside surface has progressed beyond the web and flange junction.

When heating the inside flange surface, the truncated end of the heating triangle shall be just inside the junction of web and flange and the triangle shall share a common base with the heating pattern on the outside of the flange at that point.

The heating torches shall be manipulated to guard against general and surface overheating. When heating thick plates, it may be necessary to occasionally interrupt heating for periods of less than 1 minute to allow the heat to soak into the flange and avoid surface overheating.

501.9. Location of Heating Patterns. Heating patterns shall be spaced uniformly along the full length of each flange to produce a uniform circular (not parabolic) curvature where required by the Contract Documents. Sufficient heating patterns shall be used in each piece to eliminate unsightly chording effects. Heating patterns shall be adjusted within the limits described above to produce the necessary curvature, compensating for differences in flange thickness and width as necessary. Thicker and wider plates in general require wider heating patterns to produce the same amount of curvature. Care shall be taken when heating relatively thin, wide plates to guard against flange buckling.

501.10. Heat Measurement. The Contractor shall provide the inspector with temperature indicating crayons manufactured for 600 degrees F., 1,000 degrees F., 1,100 degrees F., and 1,250 degrees F.

501.11. Artificial Cooling. 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 degrees F.

501.12. Control of Web and Flange Distortion. Web distortion is the first indication that the heating process is not being conducted properly. Web or flange distortion in excess of that allowed by the Specifications will not be permitted. When intermediate stiffeners are placed on only one side of a girder web, temporary intermediate braces (wood blocks or posts are sufficient) must be placed on the opposite side during heating to prevent rotation of the flange during the heating process. One-quarter inch asbestos sheet material shall be placed against the web before applying heat to the inside flange surface. When heating the inside flange surface, the torches shall be directed so as to prevent applying heat directly to the web. The asbestos sheet material may be a 2 ft. x 2 ft. x 0 in. piece that the workmen move from pattern to pattern as the work progresses.

501.13. Web Cutting for Heat-Curved Welded Plate Girders. The fabricator shall cut sufficient extra camber into the webs of plate girders to provide for all camber losses during fabrication and heat curving. (The heat-curving process will in general not cause as much camber loss during fabrication as welding of the web to flanges and welding of stiffeners and connection plates to the compression flange.)
The Department will accept members with moderately excessive camber that will not interfere with the construction of the superstructure slab. When this is not possible, corrections of moderately excessive camber will be approved by the heat-shrink process. Camber deficiencies which place the member on the same side of theoretical lines as superstructure dead load deflections may only be corrected by heat-shrink procedures approved by the D.C.E.S.

501.14. Rolled Beams with Cover Plates. When members are fabricated with cover plates attached to rolled beams, the cover plates may be attached before heat curving if the total thickness of one flange plus cover plate is less than 2½ inches and the radius of curvature is greater than 1,000 feet minimum. When rolled beams with cover plates attached are heat curved, the Contractor shall magnetic particle inspect the fillet welds between the flange and cover plate. This work shall be done after all heating is complete. It shall conform to the requirements of Section VIII and shall be done at no additional cost to the State.

All other rolled beams with cover plates must be heat curved before the cover plates are attached. The cover plates shall be either heat curved or flame cut to the required radius separately before being welded to the curved beam.

501.15. Dimensional Tolerances. Before acceptance at the shop and after erection, all stringers and girders for bridges shall meet the dimensional tolerances as specified in Par. 205.4. The procedure to be followed in measuring dimensional tolerances is as follows:

a. Camber will be measured with the member lying on its side before heat curving.

b. Curvature shall be measured as the offset from string lines or wires attached to both the top and bottom flanges. The shop drawings shall show the required offset for each 10 feet of length. The member shall be supported with the web vertical but without restriction against horizontal movement when these measurements are made.

c. The final camber measurement will be made by the Engineer in the field after erection. At the time of this measurement, the members shall have all of the specified camber less the dead load deflection of the steel as specified in Par. 205.4.

   The D.C.E.S. may approve excessive camber without repair as stated in par. 501.13.

d. Corrections for flange and web distortion not within the limits of the Contract Documents may be made by heat-shrink procedures approved by the D.C.E.S.

501.16. Handling, Transport and Erection. Curved stringers and girders shall be properly braced and supported at all times to prevent damage from torsional, vertical, and lateral deflection. Members damaged during handling, transport, or erection will be subject to nondestructive tests and repaired or replaced as ordered by the D.C.E.S. The costs of all tests, repair, or replacement will be borne by the Contractor.

Curved members shall not be shipped with the webs horizontal unless the method of loading and bracing has the prior approval of the D.C.E.S.

502. HEAT CAMBERING OF ROLLED BEAMS AND WELDED PLATE GIRDERS

502.1. General. When heat cambering is approved, only deep-Vee heating will be permitted.

Small localized heats may be limited to flange material only when minor reductions in camber are required. Major reductions in camber must be done by deep-Vee heating to prevent web distortion.

502.2. Heat Cambering of Rolled Beams. Rolled beams may be heat cambered to provide the required parabolic vertical curvature. Triangular heating patterns shall be spaced throughout the length of the member to provide the required curvature. The apex of the heating triangle shall be located at a point not less than 75 percent of the depth of the member measured from the flange that will be concave after cambering.
The heating pattern shall have a total included angle not exceeding 20 degrees. Heating shall begin at the apex of the heating pattern and progress slowly towards the base of the pattern as each area is brought up to temperature as stated in Par. 501.7. The heating torch shall not be returned to the apex of the heating triangle after heating has progressed towards the base.

The heating torches shall not begin to progress toward the base of the heating pattern until the apex of the pattern has been brought up to the specified temperature. Heating shall continue until the base of the triangular heating pattern is brought up to the required temperature across the full width of the flange.

When rolled beams are to be fabricated with cover plates, the rolled beams shall be heat cambered prior to the attachment of cover plates.

All detail material such as connection plates, bearing stiffeners, and gusset plates attached to the member shall be welded to the rolled beam after the beam has been heat cambered as required by the Contract Documents.

502.3. Heat Cambering of Welded Plate Girders. Heat cambering of welded plate girders will only be approved as a necessary repair procedure for plate girders rejected for improper camber. See Par. 501.13.

When it is necessary to correct camber deficiencies in welded plate girders, heating will be permitted in deep-Vee heating patterns centered on intermediate stiffeners and connection plates.

The apex of the heating pattern shall be located not less than \( \frac{1}{6} \) of the depth of the member from the flange that will be concave after cambering. The maximum included angle of the heating pattern shall be 10°. The maximum width of the base of the heating pattern shall be 10 inches. Where shallow members or thin webs prescribe heating patterns with a width substantially less than 10 inches at the junction of the web to flange, the heating pattern in the flange at that location may extend beyond the limits of the heating pattern in the web by a maximum of 1 inch provided the total width of pattern in the flange does not exceed the 10-inch limit stated above.

502.4. Support of Members for Heat Cambering. Members to be heat cambered shall be supported with the web vertical and with the flange which will be concave after cambering placed upwards. Supports shall be spaced to take the maximum advantage of dead load in the member before heat is applied.

No combination of support system or external load shall be placed on the member that will cause a compressive stress in the flange to exceed 20,000 psi before heating.

502.5. General Provisions. The provisions of the following paragraphs in the heat curving specification shall apply equally to heat cambering:

Paragraph 501.7, Heating Process and Equipment
Paragraph 501.10, Heat Measurement
Paragraph 501.11, Artificial Cooling
Paragraph 501.13, Web Cutting for Heat-Curved Welded Plate Girders
Paragraph 501.15, Dimensional Tolerances
Paragraph 501.16, Handling, Transport and Erection
SECTION VI

RADIOGRAPHIC INSPECTION OF GROOVE WELDS IN BUTT JOINTS

601. GENERAL. The procedures and standards herein described are specifically designed to facilitate the performance and recordation of radiographic examination of groove welds in butt joints by X-ray or gamma ray sources. All radiographic inspection performed by State forces, inspection agencies under contract to the State, Contractors or their agents working on State contracts shall conform to the requirements of this specification.

602. EXTENT OF INSPECTION.

602.1. Joints to be Radiographed. All butt joints in primary tension members shall be radiographed. This shall include all tension flange butt welds and the tension portion of web butt welds in stringers and girders. Joints to be radiographed shall also include tension butt welds in columns, bents, towers, rigid frames, arches, truss chords, truss web members and longitudinal stiffener splice welds when attached to the tension areas of members.

Radiographic inspection will be used to determine the soundness of tension butt welds throughout their entire length unless otherwise specified.

When stringers and girders are supported at their ends only, all bottom flange joints are considered to be in tension unless otherwise stated. When members are continuous or cantilevered over a support, the limits of tension in each flange shall be shown on the Contract Plans and on the Shop Drawings. These limits of tension shall include the effects of “Live Loads.”

602.2. Web Splices. Tension areas of web splices in stringers and girders shall be interpreted to represent one-third of the web butt joint length beginning at the tension flange unless otherwise specified. A minimum of 16 inches shall be radiographed regardless of web depth. No more than one-third of the web butt weld length or 16 inches minimum need be radiographed if the length tested is determined to be acceptable. If defects are found in this area which is subject to partial examination, the area examined shall be extended to insure that the limits of the rejectable discontinuities have been discovered and repaired. If the extended area examined contains gross defects in the opinion of the Inspector, the complete weld shall be radiographed. When a web joint is subject to reversal of stress the entire web and both flange joints shall be radiographed.

602.3. Field Splices. Butt welded field splices in structural members shall be subject to 100 percent coverage by radiographic inspection unless otherwise specified.

602.4. Repairs. “Spot” inspection and “spot” radiography shall not be used except for the examination of localized repairs in welds previously rejected by radiographic tests. Repair radiographs shall be made using 17-inch long film and shall represent a minimum length of weld equal to the repair excavation plus 3 inches each side.

602.5. Radiographic Inspection of Welds Considered to be Shear or Compression Welds. Any groove weld in a butt joint may be subject to radiographic inspection regardless of the direction of stress if required by the Contract Documents or ordered by the Inspector. The Inspector shall order the radiographic inspection of compression and shear butt welds in pieces where 10 percent or more of the length of the tension butt welds are found to contain rejectable defects. The Inspector will only order radiograph inspection of compression and shear welds when there is a basis to assume they are defective as described above.

602.6. Fraudulent Radiographs. The State may order new and separate radiographic inspection of all butt welds in all structural steel fabricated for the State in a given shop when there is evidence that the Fabricator has submitted fraudulent radiographs or reports.

603. RADIOGRAPHIC TECHNIQUE AND EQUIPMENT. The welds shall be radiographed utilizing techniques and equipment that will have sufficient sensitivity to properly delineate at least two penetrators on each radiograph. Penetrators shall conform to the requirements of this specification. Radiographic quality shall be such that identification numbers of penetrators and the 2T hole shall show clearly on the radiograph, except that when Number 5, 7 and 10 penetrators are required, the slit shall appear clearly on the radiograph and the 2T hole need not appear clearly.
The density difference between the image of the holes or slit and the penetrometer image shall be the same as that between the edge of the penetrometer and the adjacent film area.

Penetrators that do not show clearly on the radiographs as described shall cause the rejection of the radiograph by the Inspector or the D.C.E.S. Penetrator images shall be of sufficient clarity to permit the measurement of both the dimensions of the penetrator and the diameter of the holes.

**604. PREPARATION OF JOINTS.** All joints shall be prepared for radiography by grinding as described in Article 203.17, Weld Profiles, as contained in this Manual.

Backing bars and runoff tabs shall be removed prior to preparation by grinding.

**605. PREPARATION FOR EXPOSURE.** All film cassettes shall be loaded with two fine grain films of the same specification. Appropriate lead screens shall be used. A center screen is recommended when the steel thickness exceeds 1 1/4 inches. The loaded cassette shall be held in intimate contact with the steel by a process that will avoid film pressure marks. The back side of the cassette shall be protected from scatter radiation for its full length by a lead sheet.

Radiographs shall be made with a single source of radiation placed on a line directly above and perpendicular to the plane of interest. In general, this will be the center of the length to be examined. The source-to-subject distance shall be not less than the total length of film being exposed. In addition, the source-to-subject distance shall not be less than the amount shown in the following table:

<table>
<thead>
<tr>
<th>Maximum Thickness of Weld Under Examination (T)</th>
<th>Minimum Source-to Subject Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4&quot; to 2&quot; incl.</td>
<td>24&quot;</td>
</tr>
<tr>
<td>≥ 2&quot; to 2 1/2&quot; incl.</td>
<td>18&quot;</td>
</tr>
<tr>
<td>≥ 2 1/2&quot;</td>
<td>7T</td>
</tr>
</tbody>
</table>

**606. RADIOGRAPHIC SOURCE.** X-ray or Iridium 192 may be used as a source for all radiography. Cobalt 60 may only be used as a radioactive source when the steel being radiographed exceeds 3 inches in thickness.

**607. PENETRAMETERS.** At least two penetrators shall show clearly on each radiograph. The penetrators shall always be placed on the source side of the joint being radiographed.

Penetrators shall be placed parallel to the weld joint with the holes at the outer end as shown in Figure 611. Penetrators shall be of the thickness or thicknesses required by Table 607.

Penetrators shall be manufactured from steel, preferably stainless steel, to conform to the dimensions shown in Figures 607. (a) and 607. (b).

Penetrators shall be identified by number in symbols at least 3/32 inches high.

Each penetrator shall be manufactured with three holes, one of which shall be of a diameter equal to twice the penetrator thickness (2T) but not less than 1/16 inch. The diameter of the two remaining holes shall be selected by the manufacturer. They will ordinarily be equal to three times (3T) and four times (4T) the penetrator thickness but they need not be smaller than 1/16 inch.

When a transition in thickness occurs at a welded joint, a minimum of one penetrator shall be used for each plate thickness. When it is necessary to radiograph a joint representing a major change in thickness, the penetrator representing the maximum plate thickness may be placed on the sloping surface of the base metal outside the weld zone. When it is necessary to place a penetrator on the sloping surface, and such penetrator represents a thickness substantially greater than that being radiographed, each radiograph shall clearly show the image of a penetrator of the proper thickness for the thinner portion of the joint at each edge of the radiograph in addition to the penetrator on the sloping surface.
Fig. 607a — Details of Penetrameters.
Fig. 607b – Penetrameter (Image Quality Indicator)
Table 607.

<table>
<thead>
<tr>
<th>Steel Thickness Range</th>
<th>Thickness of Penetrameter</th>
<th>Designation on Penetrameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1/4 in. incl.</td>
<td>0.005 in.</td>
<td>5</td>
</tr>
<tr>
<td>Over 1/4 in. thru 3/8 in.</td>
<td>0.0075 in.</td>
<td>7</td>
</tr>
<tr>
<td>Over 3/8 in. thru 1/2 in.</td>
<td>0.010 in.</td>
<td>10</td>
</tr>
<tr>
<td>Over 1/2 in. thru 5/8 in.</td>
<td>0.0125 in.</td>
<td>12</td>
</tr>
<tr>
<td>Over 5/8 in. thru 3/4 in.</td>
<td>0.015 in.</td>
<td>15</td>
</tr>
<tr>
<td>Over 3/4 in. thru 7/8 in.</td>
<td>0.0175 in.</td>
<td>17</td>
</tr>
<tr>
<td>Over 7/8 in. thru 1 in.</td>
<td>0.020 in.</td>
<td>20</td>
</tr>
<tr>
<td>Over 1 in. thru 1 - 1/4 in.</td>
<td>0.025 in.</td>
<td>25</td>
</tr>
<tr>
<td>Over 1 - 1/4 in. thru 1 - 1/2 in.</td>
<td>0.030 in.</td>
<td>30</td>
</tr>
<tr>
<td>Over 1 - 1/2 in. thru 2 in.</td>
<td>0.035 in.</td>
<td>35</td>
</tr>
<tr>
<td>Over 2 in. thru 2 - 1/2 in.</td>
<td>0.040 in.</td>
<td>40</td>
</tr>
<tr>
<td>Over 2 - 1/2 in. thru 3 in.</td>
<td>0.045 in.</td>
<td>45</td>
</tr>
<tr>
<td>Over 3 in. thru 4 in.</td>
<td>0.050 in.</td>
<td>50</td>
</tr>
<tr>
<td>Over 4 in. thru 6 in.</td>
<td>0.060 in.</td>
<td>60</td>
</tr>
<tr>
<td>Over 6 in. thru 8 in.</td>
<td>0.080 in.</td>
<td>80</td>
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</tbody>
</table>

608. CONTINUITY OF INSPECTION. Welded joints shall be radiographed and the film indexed in a manner that will provide complete and continuous inspection of the joint within the limits specified. Joint limits must be shown clearly on the radiograph. Short film, short screens, excessive undercut by scatter radiation, or any other process that obscures joint edges will render the radiograph unacceptable. Films should have sufficient length to produce ½ inch of "black" (film exposed to direct radiation from the source) beyond each plate edge.

In general, webs and flanges shall be radiographed before the member is assembled. When, because of some unusual situation, it is necessary to radiograph a member which has already been assembled (a tee conformation), the source shall be placed between the flanges and the film shall be placed against the outside flange surface such that both the flange edge and the web-to-flange welds are clearly delineated on the film. A similar technique shall be used for radiographing webs of members already assembled.

609. FILM SIZE. When the joint thickness is less than 3 inches, radiographs may be 4½ in. x 17 in. in size. When the length of the joint is such that more than one radiograph is required, one of the films may be shortened to 4½ inches x 10 inches if the Contractor elects to do so. When joint thicknesses are 3 inches or greater, the minimum film size shall be 7 inches x 17 inches. Larger radiographs may be required in areas where there have been excessive repairs, to radiograph cope hole closure welds or joints with unusual dimensions.

610. FILM DENSITY AND QUALITY. All radiographs shall be clean and free of film processing defects. Film stains, excessive water marks, pressure marks, or artifacts caused by screen scratches, light leaks in cassettes, etc., or other deficiencies in the radiograph that interfere with interpretation shall cause rejection of the film. In general, the quality of the radiograph will be determined by the quality of the penetrator images and freedom from film defects. The use of film side penetrators shall be cause for rejection of the radiographs.

Radiographs shall have an H&D density of 1.5 minimum to 4.0 maximum. Densities within the range of 2.5 to 3.5 are preferred. When transitions in thickness are radiographed where the ratio of the thicker plate to the thinner plate is in the order of 3 to 1 or greater, radiographs should be exposed to produce a density of greater than 3.0 minimum in the thinner plate area. When this is done, densities of less than 1.5 will be accepted in the thicker plate area. Except for this condition, densities outside the maximum and minimum limits listed above will be cause for rejection of the film.

Radiographic density shall not vary by more than 0.50 in any section of equal thickness depicted in the radiograph.

All radiographs shall be reviewed on a variable intensity illuminator (viewer) of the spot-review type. The viewer shall incorporate a means of adjusting the size of the spot under examination. The viewer shall have sufficient capacity to illuminate radiographs with a density of 4.0 without difficulty. Film review shall be done in an area of subdued light.
611. FILM IDENTIFICATION. In order that films shall be properly identified for examination, filing and actual physical matching with the steel when required, the following information should appear on each film:

(a) New York State Contract Number.
(b) Initials of Radiographic Inspection Company.
(c) Initials of Fabricator and the Fabricator’s Shop Order Number.
(d) Date.
(e) Erection Mark.
(f) Weld Number and an individual Piece Mark in the event that there is a duplication of erection marks on the Contract.
(g) Location Letters.
(h) Penetrators.

See Figure 611 for details of film identification.

All the information described in this subsection shall appear on each film. The images appearing on the film shall be obtained by placing lead numbers and letters on the steel on the source side prior to exposure. The minimum height of numbers and letters shall be 5/16 inch. The Contractor will be permitted to preprint the New York State Contract Number, the name of the radiographic company, and the fabricator’s name on the radiographs by a direct light process provided that this information is not placed within 1 inch of the edge of the weld. When this preprinting technique is used, the remaining items of film identification listed above shall be produced on the radiograph by the use of lead numbers as described. The fabricator’s shop order number shall be placed on the radiograph by the use of lead numbers.

NOTE: Grease pencils and similar materials shall not be used to mark on radiographs. No identifying mark or notation shall be placed on a radiograph by any procedure that might interfere with the interpretation of the radiograph.

612. WELD IDENTIFICATION. Radiographs are identified as above described. Individual welds are identified on the film and in the radiographic inspection report based upon weld numbers assigned prior to radiography by numbering the web and flange welds from left to right beginning from the marked end as shown on the shop drawing.

613. PERMANENT STEEL IDENTIFICATION AND FILM IDENTIFICATION. Each weld joint shall be permanently die-stamped with the identifying erection mark, weld number, piece mark when required, and location letters required by this specification as shown in Figure 613.

The die-stamped numbers and letters shall be 3/8 inch to 1/2 inch high. Dies shall be lightly struck to produce the minimum impression that can be clearly seen in the absence of paint and mill scale. Low stress dies, i.e., dies manufactured to produce impressions that are rounded at the bottom of the impression rather than sharp edged, shall be used.

Lead location letters and weld numbers used to permanently identify the radiographs shall be placed directly over the impressions die stamped in the steel prior to radiography. Location letters shall be placed as shown in Figure 613. Spacing shall be somewhat random. Templates shall not be used. In general, when radiographs are viewed in register, only those films representing the same joint should have the location letters perfectly superimposed.

Care should be taken to be sure that the die-stamped impressions are not lost during any repair welding or surface preparation that follows radiography. To help insure that the exact center of weld is not lost during the work, at least two center punch marks should be placed 1.00 foot from the center of the weld. These marks may be placed on one or both sides of the weld with one impression 2 inches to 3 inches from each end of the joint.

614. RADIOGRAPHIC REPORTS AND SUBMISSION OF RADIOGRAPHS. A separate radiographic report will be required for each erection piece. The radiographic report shall be prepared by the company providing radiographic inspection services and will be subject to the review and approval of the Inspector. Radiographic reports shall conform in general to the example shown in Figure 614.

NOTE: The Radiographic Inspection Report described in Figure 614 has been completed to show the testing and repair of a fairly complex piece.
NOTE: Lead characters placed directly over characters die-stamped on the steel for the purpose of re-matching the film to the weld zone after processing.

Fig. 611 — Film and Weld Identification
## WELD LOCATION AND IDENTIFICATION SKETCH

![Weld Location Sketch]

### Table: Weld Inspection Records

<table>
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<td></td>
<td></td>
<td>SLAG-1&quot; FROM &quot;A&quot; EDGE</td>
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<td>A-B</td>
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<tr>
<td></td>
<td></td>
<td>B-C</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:**
- SLAG - WITHIN CODE

---

**Radiographer:** X. Ray  
**Interpreter:** D. Fect  
**Inspector:** S. Holmes

---

**Fig. 614 — Sample Radiographic Inspection Report**
I. To determine the maximum size of defect permitted in any one joint or weld throat thickness:
   Project (A) horizontally to (B)

II. To determine the minimum clearance allowed between edges of defects of any size:
   Project (B) vertically to (C)

C - MINIMUM CLEARANCE MEASURED ALONG THE LONGITUDINAL AXIS OF THE WELD BETWEEN EDGES OF POROSITY OR FUSION-TYPE DEFECTS
   -INCHES (Larger of Adjacent Defects Governs)

*Maximum defect size shall be less than 1/16 inch in this area. Sum of defects shall not exceed 3/16 inch within this distance from the edge or to any intersecting weld.

Fig. 615.1 – Weld Quality Requirements for Defects Occurring in Tension Welds—Bridges
   (Limitations of Porosity and Fusion-Type Defects)
A schematic drawing of the complete erection piece shall appear at the top of the sheet and shall show all points of support for the piece. The thickness and width or length of all joints shall be shown on the drawing. The required penetrant designation shall be shown adjacent to the joint. The direction of lettering of web welds shall be shown. Each individual radiograph shall be listed as accepted or rejected. All visible discontinuities shall be explained. No films shall be forwarded to the State as accepted that contain any indication that could be interpreted as a rejectable discontinuity. The explanation that this is a surface indication is only acceptable under unusual conditions. Surface marks except the die-stamp indications required by the specifications should be removed before the joint is radiographed.

All repair welds shall be identified in the report and in the radiograph by the letter “R” following the radiograph identification. The first repair shall be designated “R1,” the second “R2,” etc.

The radiographs for each erection piece and the radiographic inspection report describing the piece shall remain in the plant until the last joint to be radiographed in that piece is accepted. The repair and acceptance of each joint shall be placed in logical order in the report. When the last joint in the piece is interpreted to be acceptable by the radiographer representing the fabricator, the film and report for that joint shall be submitted to the Inspector for review as required for each day’s radiography. When the Inspector accepts this final joint, one radiograph for each joint represented in the piece shall be presented to the Inspector with two copies of the completed radiographic inspection report for submission to the D.C.E.S. If the fabricator would prefer to mail the radiographs and reports directly to the State after approval by the Inspector, this procedure is acceptable. Films and reports are to be forwarded to the D.C.E.S. not later than two business days following the acceptance of the last joint in the piece.

The radiographic inspection report for the last erection piece requiring radiography on each shop order shall be clearly identified as the final report for that shop order.

The State will endeavor to review radiographs promptly as they are received. The State’s review and disposition of radiographs and radiographic inspection reports is final. The D.C.E.S. may reject radiographs and/or reports that have previously been accepted by a radiographic inspection company and approved by an Inspector representing the State.

The State assumes no responsibility for the improper interpretation of radiographs or reports by others. Prompt review by the State is designed to prevent the discovery of defects after the steel has been shipped from the plant whenever possible. However, should the steel be shipped and erected prior to the discovery of rejectable defects, all costs associated with the repair of such defects shall be the responsibility of the Contractor.

The final review provided by the State is designed to monitor the effectiveness of the work performed by the radiographer and the shop inspector. The State does not issue letters of acceptance. Radiographs may be considered acceptable unless otherwise notified by the State.

The Fabricator and the Inspector will be notified by mail of all radiographs found unacceptable by the State. Unacceptable radiographs will be retained by the State, together with all subsequent repair radiographs. Radiographs required as a result of films or welds rejected by the D.C.E.S. shall be submitted separate from other radiographs and shall be accompanied by a letter that answers all questions raised in the State rejection notice.

615. STANDARDS OF ACCEPTANCE. Welds subject to radiographic inspection shall have no cracks regardless of the direction of stress or type of structure. Porosity or fusion-type defects shall be evaluated by the following criteria.

615.1. Tension Welds in Bridges. The greatest dimension of any porosity or fusion-type defect that is 1/16-inch or larger in greatest dimension shall not exceed the size, B-Dimension of Defect, indicated in Fig. 615.1 for the effective throat thickness or weld size involved. The distance from any porosity or fusion-type defect described above to another such defect, to an edge or to any intersecting weld shall not be less than C-Minimum Clearance Allowed, indicated in Fig. 615.1 for the size of defect under examination.

NOTE: When two such defects can be measured as a single defect from the extreme limits of the two defects, including the space between the defects, and the combined length of defect does not exceed the size, B-Dimension of Defects, indicated by Fig. 615.1 for the effective throat thickness or weld size involved, no repair shall be required.
The limitations given by Fig. 615.1 for a 1½ in. joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

Unless otherwise restricted by Fig. 615.1 the sum of the greatest dimension of porosity and fusion-type defects less than 1/16 inch in greatest dimension shall not exceed 3/8 inch in any linear inch of weld.

615.2. Compression and Shear Welds in Bridges. The greatest dimension of any porosity or fusion-type defect that is 1/8 inch or larger in greatest dimension shall not exceed the size, B-Dimension of Defects, indicated in Fig. 615.2 for the effective throat thickness or weld size involved. The distance from any porosity or fusion-type defect described above to another such defect, to an edge or to any intersecting weld shall not be less than C-Minimum Clearance Allowed, indicated by Fig. 615.2 for the size of defect under examination.

NOTE: When two such defects can be measured as a single defect from the extreme limits of the two defects, including the space between the defects, and the combined length of defect does not exceed the size, B-Dimension of Defects, indicated by Fig. 615.2 for the effective throat thickness or weld size involved, no repairs shall be required.

The limitations given by Fig. 615.2 for 1½-inch joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

Unless otherwise restricted by Fig. 615.2 the sum of the greatest dimension of porosity and fusion-type defects less than 1/16 inch in greatest dimension shall not exceed 3/8-inch in any linear inch of weld.

615.3. Welds in Buildings. Porosity or fusion-type defects having a greatest dimension of 3/32 inch or greater shall be unacceptable if they exceed the following limits:

615.3.1. The greatest dimension of the defect is larger than 2/3 of the effective throat thickness or 2/3 the weld size or ¼-inch.

615.3.2. The defect is closer than three times its greatest dimension to the end of a groove weld subject to tension.

615.3.3. A group of such defects in line when:

(a) The sum of the greatest dimensions of all such defects is larger than the effective joint thickness or weld size in any length of six times the effective joint thickness or weld size. When the length of the weld being examined is less than six times the effective thickness or weld size, the permissible sum of the greatest dimensions shall be proportionally less than the effective throat thickness or weld size.

(b) The space between two such defects which are adjacent is less than three times the greatest dimension of the larger of the defects in the pair being considered.

NOTE: When two such defects can be measured as a single defect from the extreme limits of the two defects, including the space between the defects, and the combined defects are still accepted under the provisions specified above, no repair shall be required.

615.3.4. Independent of the requirements of the above paragraphs, defects having a greatest dimension of less than 3/32-inch are considered unacceptable defects if the sum of their greatest dimensions exceeds 3/8-inch in any linear inch of weld.
I. To determine the maximum size of defect permitted in any joint or weld throat thickness:
   Project (A) horizontally to (B)

II. To determine the minimum clearance allowed between edges of defects of any size:
    Project (B) vertically to (C)

C - MINIMUM CLEARANCE MEASURED ALONG THE LONGITUDINAL AXIS OF THE WELD BETWEEN EDGES OF POROSITY OR FUSION-TYPE DEFECTS - (IN.) (Larger of Adjacent Defects Governs)

*The maximum size of defect located within this distance from an edge or intersection of a weld shall be 1/8 inch, but a 1/8-inch defect must be 1/4 inch or more away from the edge or intersection. The sum of defects equal to or less than 1/8 inch in size and located within this distance from the edge or intersection shall not exceed 3/16 inch. Defects 1/16 inch to less than 1/8 inch will not be restricted in other locations, unless they are separated by less than 2L (L being the length of the larger defect) in which case the defects shall be measured as one length equal to the total length of the defects and spaces and evaluated by this Figure.

Fig. 615.2 - Weld Quality Requirements for Defects Occurring in Compression Welds—Bridges
   (Limitations of Porosity and Fusion-Type Defects)
SECTION VII
ULTRASONIC TESTING OF GROOVE WELDS AND BASE METAL
USING STRAIGHT AND ANGLE BEAM SEARCH UNITS

701. GENERAL. The procedures and standards set forth in this Section shall govern the ultrasonic testing of groove welds between the thicknesses of 5/16 and 8 inches, inclusive, when such testing is required by the Contract Documents. Provision is also made for base metal soundness tests using straight beam search units.

Variations in testing procedures, equipment and acceptance standards not included in this section may only be used with the approval of the D.C.E.S. Such variations include other thicknesses, weld geometries, search unit (transducer) sizes, frequencies, couplant, etc.

Electrogas and electroslag welds shall be subject to radiographic inspection in addition to the ultrasonic tests required by the Contract Documents.

702. EXTENT OF TESTING. Testing shall be performed where and as required by the Contract Documents.

703. PERSONNEL QUALIFICATION. Personnel performing ultrasonic testing shall be qualified by written and performance tests administered by the State unless otherwise approved by the D.C.E.S.

704. ULTRASONIC EQUIPMENT.

704.1. General. The ultrasonic test instrument shall be of the pulse-echo type. It shall generate, receive, and present on a cathode-ray tube (CRT) screen, pulses in the frequency range from one to six megahertz (MHz). The presentation on the CRT screen shall be the “Video” type and characterized by a clean, crisp trace.

704.2. Horizontal Linearity. The horizontal linearity of the test instrument shall be within plus or minus 5 percent over the linear range which shall include 90 percent of the sweep length presented on the CRT screen for the longest sound path to be used. The horizontal linearity shall be measured by techniques approved by the D.C.E.S.

704.3. Voltage Stabilization. The test instrument shall be equipped with an internal electronic circuit or an external voltage transformer to stabilize the operating voltage. In either case, stabilization must be achieved within plus or minus 2 volts over an input voltage range of 90 to 130 volts.

Test instruments utilizing battery power shall include internal stabilization resulting in no greater variation than plus or minus 1 decibel following warm-up during battery operating life. There shall be an alarm or meter incorporated in battery powered instruments to signal a drop in voltage prior to instrument shutoff because of battery exhaustion.

704.4. Calibrated Gain Control. The test instrument shall have a calibrated gain control (attenuator) adjustable in discrete 1 or 2 decibel steps over a range of at least 60 decibels. The accuracy of the gain control settings shall be within plus or minus 1 decibel.

704.5. Dynamic Range. The dynamic range of the instrument’s CRT display shall be such that a difference of 1 decibel of amplitude can be easily detectable on the CRT.

704.6. Straight Beam Search Units. Straight beam search units (transducers) shall have an active area of not less than ½ square inch nor more than 1 square inch. The transducer shall be round or square. Transducer frequency shall be 2 to 2.5 MHz. Transducers shall be capable of resolving the three reflections as described in Figure 700C (1C).

*In bridge construction, this specification only provides for testing in thicknesses of 5/16 to 6-inches inclusive. Ultrasonic testing of welds in bridges, where the thickness exceeds 6 inches, will be subject to the provisions of a separate individual job specification.
704.7. Angle Beam Search Units. Angle beam search units (also referred to as transducers) shall consist of a transducer and an angle wedge. The unit may be comprised of the two separate elements or be an integral unit.

704.7.1. The transducer frequency shall be between 2 and 2.5 MHz, inclusive.

704.7.2. The transducer crystal may vary in size from ½ to 1 inch in width and from ½ to 13/16 inches in height (see sketch).

704.7.3. Angle beam search units shall produce a sound beam in the material being tested within plus or minus 2 degrees of the following proper angle: 70°, 60°, or 45°, as described in Figure 700C (II B).

704.7.4. Each search unit shall be marked to clearly indicate the frequency of the transducer, nominal angle of refraction, and index point. The index point location procedure is described in Figure 700C (II A).

704.7.5. Internal reflections from angle beam search units with a screen presentation higher than the horizontal reference line appearing on the screen to the right of the sound entry point shall not occur beyond ½ inch equivalent distance in steel when the sensitivity is set as follows: 20 db's more than that required to produce a maximized horizontal reference line height indication from the 1.5 mm (.06") diameter hole in the International Institute of Welding IIW reference block (Figure 700A).

704.7.6. The dimensions of the search unit shall be such that the closeness of approach to the weld reinforcement shall not exceed the requirements of Figure 700C (II F), Approach Distance of Search Unit. The search unit shall be positioned for maximum indication from the .06-inch diameter hole in the IIW calibration block.

704.7.7. The combination of search unit and instrument shall resolve the three holes in the resolution test block shown in Figure 700D. The search unit position is described in Figure 700C (II E). The resolution shall be evaluated with the instrument controls set at normal test settings and with indications from the holes brought to mid screen height.

705. CALIBRATION STANDARDS. The International Institute of Welding's (IIW) ultrasonic reference block, shown in Figure 700A, shall be the standard used for both distance and sensitivity calibration. More portable reference blocks of other designs may be used provided they meet the requirements of this specification and are referenced back to the IIW Block. Approved designs are shown in Figure 700B. Differences between alternate calibration blocks and the IIW Block shall be accounted for in determining the Reference Level and Defect Rating.

Use of a "corner" reflector for calibration purposes is prohibited.

706. EQUIPMENT CALIBRATION.

706.1. Calibrated Gain Control. The instrument's gain control (attenuator) shall be checked for correct calibration at two-month intervals in accordance with a procedure approved by the instrument's manufacturer and shall meet the requirement of Paragraph 704.5.

706.2. Horizontal Linearity. Horizontal linearity shall be checked after each 40 hours of instrument use by techniques prescribed in Paragraph 704.2.
706.3. Checking of Angle Beam Search Units. Each angle beam search unit shall be checked after each 8 hours of use to determine that the contact face is flat, that the sound entry point is correct, and that the beam angle is within the permitted plus or minus 2 degrees tolerance. Tests shall be made using an approved calibration block. Search units which do not meet these requirements shall be corrected or replaced.

707. CALIBRATION FOR TESTING.

707.1. General. Calibration for sensitivity and horizontal sweep (distance) shall be made by the ultrasonic operator just prior to and at the location of testing of each weld and at intervals of 30 minutes as testing proceeds. Recalibration shall be made each time there is a change of operators, when transducers (search units) or cables are changed, when new batteries are installed, when equipment operating from a 110-volt source is connected to a different power outlet or whenever the electrical circuitry is disturbed in any way.

Ultrasound test instruments equipped to produce more than one signal intensity (pulse energy) shall be calibrated and operated at the lowest setting (Pulse Energy I) unless otherwise stated in the Ultrasonic Test Report and approved by the D.C.E.S.

Clipping controls, suppression controls or any control whose function is to filter the CRT presentation shall not be used without the prior approval of the D.C.E.S. When the use of these controls is approved, it shall be clearly noted in the ultrasonic test report. The clipping control shall not be changed following calibration or during testing.

707.2. Calibration for straight beam testing.

707.2.1. The horizontal sweep shall be adjusted for distance calibration to present the equivalent of at least two plate thicknesses on the CRT screen.

707.2.2. The sensitivity shall be adjusted at a location free of indications so that the first back reflection from the far side of the plate will be between 50 and 80 percent of full screen height.

707.3. Calibration for angle beam testing.

707.3.1. The horizontal sweep shall be adjusted to represent the actual sound path length by using acceptable distance calibration blocks shown in Figures 700A, and 700B. This distance calibration shall be made using either the 5-inch scale or 10-inch scale on the CRT screen, whichever is appropriate, unless joint configuration or thickness prevents full examination of the weld at either of these settings. The search unit position is described in Figure 700C (H D). When areas of joints are to be tested where the sound path is greater than 10 inches, those areas shall be tested with the instrument calibrated to the 15- or 20-inch scale, as appropriate. All other areas of the joint shall be tested with the instrument adjusted to the 10-inch scale.

707.3.2. With the unit adjusted to conform with the requirements of Art. 704 the sensitivity shall be adjusted by the use of the gain control (attenuator) so that a horizontal reference level trace deflection results on the CRT screen with the maximum indication from the 0.06-inch diameter hole in the H1W block or from the equivalent reference reflector in other acceptable calibration blocks. The search unit position is described in Figure 700C (H D). This basic sensitivity then becomes the zero reference level for discontinuity evaluation and shall be recorded on the ultrasonic test reports under “Reference Level,” “b,” Figure 700F.

708. TESTING PROCEDURE; GENERAL. A “Y” accompanied with a weld identification number shall be clearly marked on the material adjacent to the weld at the left end or top of each weld which is ultrasonically tested. This identification number shall serve as an orientation direction for weld discontinuity location and as the “Weld Identification” on the Ultrasonic Test Report.

All surfaces to which a search unit is applied shall be free of weld spatter, dirt, grease, oil, loose scale and paint and shall have a flat contour permitting intimate coupling.
A couplant shall be used between the search unit and the material. The couplant shall be either glycerin with a wetting agent added if needed, or a cellulose gum and water mixture of a suitable consistency. Light machine oil or equivalent may be used for couplant on calibration blocks. Tests shall verify that the couplant used during calibration produces the same sensitivity as the couplant used during testing. Any variation shall be compensated for as approved by the D.C.E.S.

**709. TESTING PROCEDURE: STRAIGHT BEAM SEARCH UNITS**

**709.1. Lamination Test Prior to Weld Test.** The entire base metal through which ultrasound must travel to test the weld shall be tested for laminar reflectors using a straight beam search unit conforming to the requirements of Paragraph 704.6, and calibrated in accordance with Paragraph 707.2. If any area of base metal exhibits loss of back reflection considered rejectable by the "Amplitude" method of lamination testing as described in Paragraph 709.4, and is located in a position that would interfere with the normal weld scanning procedure, the following alternate weld scanning procedure shall be used:

Determine the area of the laminar reflector, its depth from the surface, and record the data in the ultrasonic test report.

Grind both faces of the weld flush if necessary to attain full ultrasonic coverage.

Using applicable scanning pattern shown in Figure 700E, examine the inaccessible part of the weld by testing from both faces in order to attain full weld evaluation.

**709.2. Laminations Adjacent to Tension Groove Welds.** If laminar defects are found by visual or nondestructive tests adjacent to tension groove welds, the base metal shall be tested for soundness in accordance with the following procedure:

The end 6 inches of the plate or shape adjacent to the tension groove weld shall be divided into two equal areas for testing. Each area shall measure 3 inches in the direction of the length of the plate or shape, and shall extend for the full width of the section.

The instrument shall be calibrated in accordance with Paragraph 707.2 using a straight beam search unit conforming to the requirements of Paragraph 704.6. The test pattern shall overlap to insure 100% inspection. The end 6 inches of the plate shall be tested by the "Total Loss of Back Reflection Method" as described in Paragraph 709.3. Any lamination found to be rejectable by this test shall cause the rejection of the steel for use adjacent to a tension groove weld.

If rejectable defects are not discovered by the "Total Loss of Back Reflection Method," the end 3 inch wide strip shall be retested using the "Amplitude Method" as described in Par. 709.4. Any lamination found rejectable by this test shall cause rejection of the steel for use adjacent to a tension groove weld.

The steel shall also be rejected for use adjacent to tension groove welds if the results of the magnetic particle inspection required by Par. 202.2.2 reveals defects in excess of the limits specified by Par. 202.2.2.1.4.

**709.3. Total Loss of Back Reflection Method.** The instrument shall be adjusted as described in Paragraphs 707.2.1 and 707.2.2. With no further adjustment to the instrument, the specified area of the base metal shall be searched for laminations. Any area found to exhibit total loss of back reflection will be rejected. When the defect is located at the mid-thickness of the plate, total loss of back reflection shall be indicated on the screen when the multiple echoes from the defect are found to have a normal decay pattern.

**709.4. Amplitude Method.** The horizontal sweep shall be adjusted as described in Paragraph 707.2.1. The sensitivity shall be adjusted as described in Paragraph 707.2.2 and the amplitude of the first back reflection shall be recorded as the reference level. No further adjustments of the instrument will be made. All discontinuities which produce an indication on the screen which equals or exceeds the reference level indication shall be rejected.
710. TEST PROCEDURE: ANGLE BEAM SEARCH UNITS.

710.1. Calibration. Welds shall be tested using an angle beam search unit conforming to the requirements of Paragraph 704.7 with the instrument calibrated in accordance with Paragraph 707.3 using the angle or angles shown in Table 700A. Following calibration and during testing, the only instrument adjustment permitted is in the sensitivity level adjustment with the calibrated gain control or attenuator. Sensitivity shall be increased from the reference level for weld scanning in accordance with Table 700B for Bridges or 700 C for Buildings.

710.2. Scanning Pattern. All welds shall be scanned from both sides on the same face where mechanically possible, for longitudinal and transverse discontinuities using the applicable scanning pattern or patterns shown in Figure 700F. Testing from the opposite face may be required so it is never necessary to evaluate reflectors in the first inch of sound path from the angle beam search unit.

710.3. Transducers. The testing angle or angles shall be as shown in Table 700A and the transducer size must conform to Paragraph 704.7.2.

710.4. Defect Level. When a discontinuity indication appears on the screen at scanning level, the maximum attainable indication from the discontinuity shall be adjusted to produce a horizontal reference level trace deflection on the CRT screen. This adjustment shall be made with the calibrated gain control or attenuator, and the instrument reading in decibels, shall be recorded on the Ultrasonic Test Report, Figure 700F, under the heading “Defect Level,” “a.”

710.5. Attenuation Factor. The “Attenuation Factor,” “b” on the test report, Figure 700F is attained by subtracting 1 inch from the sound path distance and multiplying the remainder by two.

710.6. Defect Rating. The “Defect Rating,” “d” on the test report, Figure 700F, is the difference between the “Reference Level” and the “Defect Level” after the “Defect Level” has been corrected by the “Attenuation Factor.”

\[
\text{Instruments with gain in DB: } a-b-c=d \\
\text{Instruments with attenuation in DB: } b-a-c=d
\]

710.7. Defect Length. The length of a discontinuity as entered under “Defect Length” on the test report, Figure 700F, shall be determined by locating the points at each end at which the indication amplitude drops or rises 6 decibels, and measuring between the points from the center of the transducer at one end to the center of the transducer at the other end. Contiguous discontinuities with defect ratings that vary by more than six decibels shall be recorded as separate discontinuities.

710.8. Acceptance Criteria. Each weld discontinuity shall be accepted or rejected on the basis of its defect rating and its length and location in accordance with Table 700B for Bridges or Table 700C for Buildings, whichever is appropriate.

710.9. Defect Location. Each rejectable discontinuity shall be indicated on the weld by a mark directly over the discontinuity for its entire length. The depth from the surface shall be noted on nearby base metal.

710.10. Repairs. Welds found unacceptable by ultrasonic testing shall be repaired by methods permitted by Article 203.20.

711. PREPARATION AND DISPOSITION OF REPORTS. An Ultrasonic Test Report which clearly identifies the work and the area of inspection shall be completed by the ultrasonic technician at the time of inspection. The report form for welds shall contain sufficient information to identify the weld, the ultrasonic technician (signature), and the disposition (accepted or rejected).

The Contract Number, Date, etc., shall be on the Ultrasonic Test Report as shown in Figure 700F. All rejectable discontinuities shall be recorded in the test report. Other discontinuities shall be recorded if the defect rating is less than +6 db for Buildings or +10 db for Bridges. Repaired welds shall be retested ultrasonically and recorded on a continuation of the original report form.
Prior to acceptance of a weld subject to ultrasonic inspection by the Contractor for the State, all of the Report Forms pertaining to the weld, including any that show unacceptable quality prior to repair, shall be submitted to the Inspector.

When the Contract Documents require that ultrasonic tests be performed by the Contractor, the Contractor shall deliver to the D.C.E.S. a complete set of Ultrasonic Test Reports to describe all welds tested. The test reports shall describe those welds that were unacceptable prior to repair as well as other welds. The Contractor’s obligation to retain ultrasonic test reports shall cease upon delivery of this full set to the State.

712. WITNESSING OF ULTRASONIC TESTS. All ultrasonic tests required by the Contract Documents that are not performed by State forces or by an inspection agency under contract to the State shall be witnessed by a representative of the State.
NOTE:
Other IHW Approved Reference Blocks with slightly different dimensions or distance calibration slot features are permissible.

See Figure 700C for Applications
Material: ASTM A36 steel or equivalent

Fig. 700A – International Institute of Welding (IHW) Ultrasonic Reference Block
Fig. 706B—Other Calibration Blocks.
Fig. 700C—Transducer Positions
Fig. 700C (CONTINUED)—Transducer Positions
THE CALIBRATION OF THE ULTRASONIC UNIT WITH THE IIW OR OTHER APPROVED CALIBRATION BLOCKS SHOWN ON FIGURES 700A AND 700B

I. Longitudinal Mode
   A. Distance Calibration
      1. Transducer in position “G” on the IIW block, position “H” on the DC block, or position “M” on the DSC block.
      2. Adjust instrument to produce indications at 1 in., 2 in., 3 in., 4 in., etc., on the CRT.
   B. Amplitude
      1. Transducer in position “G” on the IIW block, position “H” on the DC block, or position “M” on the DSC block.
      2. Adjust gain until maximized indication from the first back reflection attains 40% – 70% screen height.
   C. Resolution
      1. Transducer in position “F” on the IIW block.
      2. Transducer and instrument should resolve all three distances.

II. Shear Wave Mode (Transverse)
   A. To locate or check the transducer sound entry point (Index Point).
      1. Transducer in position “D” on the IIW block, position “J” or “L” on the DSC block, or “I” on the DC block.
      2. Move transducer until signal from the radius is maximized.
      3. The point on the transducer which is in line with the line on the calibration block is indicative of the point of sound entry.
   B. To check or determine the transducers sound path angle.
      1. Transducer in position “B” on IIW block for angles 40° through 60°.
      2. Transducer in position “C” on IIW block for angles 60° through 70°.
      3. Transducer in position “K” on DSC block for angles 45° through 70°.
      4. Transducer in position “N” on SC block for 70° angle.
      5. Transducer in position “O” on SC block for 45° angle.
      6. Transducer in position “P” on SC block for 60° angle.
      7. Move the transducer back and forth over the line indicative of the transducer angle until the signal from the radius is maximized, then compare the sound entry point on the transducer with the angle mark on the calibration block. (Tolerance ± 2°).
   C. Distance Calibration procedure.
      1. Transducer in position “D” on the IIW (any angle).
      2. Adjust the instrument to attain indications at 4 inches and 8 or 9 inches on the CRT, 9 inches on Type 1 block or 8 inches on Type 2 block.
      3. Transducer in position “J” or “L” on the DSC block (any angle).
      4. Adjust the instrument to attain indications at 1 inch, 5 inches, and 9 inches on the CRT in the “J” position.
      5. Adjust the instrument to attain indications at 3 inches and 7 inches on the CRT in the “L” position.
      6. Transducer in position “T” on the DC block (any angle).
      7. Adjust the instrument to attain indications at 1 inch, 2 inches, 3 inches, 4 inches, etc., on the CRT.
D. Amplitude or sensitivity calibration procedure.
   1. Transducer in position “A” on the H1W block (any angle).
   2. Adjust the maximized signal from the .060-inch hole to attain a horizontal reference line height indication.
   3. Transducer in position “L” on the DSC block (any angle).
   4. Adjust the maximized signal from the 1/32-inch slot to attain a horizontal reference line height indication.
   5. Transducer on the SC block, position “N” for 70° angle, position “O” for 45° angle, or position “P” for 60° angle.
   6. Adjust the maximized signal from the 1/16-inch hole to attain a horizontal reference line height indication.
   7. This decibel reading is used as the “Reference Level” “b” reading on the “Test Report” sheet (Figure 700F.)

E. Resolution
   1. Transducer on Resolution block, position “Q” for 70° angle, position “R” for 60° angle, or position “S” for 45° angle.
   2. Transducer and instrument shall resolve the three test holes.

F. Approach Distance of Search Unit.
   1. The minimum allowable distance, “X,” between the toe of the search unit and the edge of H1W block shall be as follows:
      for 70° transducer “X” = 2 inches
      for 60° transducer “X” = 1-5/8 inches
      for 45° transducer “X” = 1 inch.
3 in. x 1 in. x 6 in. Finish all over to a maximum of 125 micro inch.

Material - ASTM A36 or equivalent.

1/16 in. Diameter holes drilled at 90 degrees to surface.

Degree lines to be scribed on surface as shown.

Degree numbers to be stenciled on surface as shown.

Fig. 700D - Angle Transducer Resolution Block.
1. Longitudinal Defects
   a. Scanning Movement "A"
      (1) Rotation Angle "a" = 10°
   b. Scanning Movement "B"
      (1) Scanning Distance "b" shall be such that the full section of weld being tested is covered.
   c. Scanning Movement "C"
      (1) Progression Distance "c" shall be approximately one-half the transducer width.

   NOTE: Movements "A", "B", and "C" are combined into one scanning pattern.

2. Transverse Defects
   a. Scanning Pattern "D" (when welds are ground flush)
   b. Scanning Pattern "E" (when weld reinforcement is not ground flush)
      (1) Scanning angle "e" = 15° maximum

   NOTE: Scanning Pattern is to be such that full weld section is covered.

3. Electroslag or Electrogas Welds (Additional Scanning Pattern)
   a. Scanning Pattern "F"
      (1) Search Unit Rotation Angle "e" between 45° and 60°

   NOTE: Scanning Pattern is to be such that full weld section is covered.

Fig. 700E - Scanning Patterns.
### Ultrasonic Testing

#### Weld Identification
- Material Thickness
- Weld Joint
- Weld Process
- Remarks

#### Plan View

![Plan View Diagram](image)

<table>
<thead>
<tr>
<th>Line Number</th>
<th>Defect Number</th>
<th>Transducer Angle</th>
<th>Node</th>
<th>DECIBELS</th>
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**NOTES:**

1. *Use Node I or II – See Glossary of Terms*
2. In order to attain “Rating d”:
   - (a) with instruments with Gain Control, use the formula: $a - b - c = d$
   - (b) with instruments with Attenuation Control, use the formula: $b - a - c = d$
   - (c) A + or - sign must accompany the “d” figure unless “d” is equal to zero
3. Distance from X is used in describing the location of a weld discontinuity in a direction perpendicular to the weld reference line. Unless this figure is zero, a + or - sign must accompany it.
4. Distance from Y is used in describing the location of a weld discontinuity in a direction parallel to the weld reference line. This figure is attained by measuring the distance from the "Y" end of the weld to the beginning of said discontinuity.
5. Make separate report following repairs. (Suffix report No. with R1, R2, etc.)

**Inspected by ___________________________**

**Date ___________________________**

**Contract No. ___________________________**

**REPORT NO. ___________________________**

**Sheet No. ________ of ________**

Fig. 700F – Ultrasonic Test Report
### TABLE 700A

#### PROCEDURE CHART

<table>
<thead>
<tr>
<th>Weld or Material Thickness</th>
<th>5/16 to 1%</th>
<th>1/2 to 1%</th>
<th>1 to 1%</th>
<th>1 1/2 to 1%</th>
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#### PROCEDURE LEGEND

**Area of Weld Thickness**

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<td>1a</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
</tr>
<tr>
<td>1b</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
</tr>
<tr>
<td>1c</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
</tr>
<tr>
<td>2</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
</tr>
<tr>
<td>3</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
<td>70° 1 and II</td>
</tr>
<tr>
<td>4</td>
<td>60° B</td>
<td>60° B</td>
<td>60° B</td>
</tr>
<tr>
<td>5</td>
<td>60° B</td>
<td>60° B</td>
<td>60° B</td>
</tr>
<tr>
<td>6</td>
<td>45° B</td>
<td>45° B</td>
<td>45° B</td>
</tr>
<tr>
<td>7</td>
<td>45° B</td>
<td>45° B</td>
<td>45° B</td>
</tr>
<tr>
<td>8</td>
<td>70° B</td>
<td>70° A B</td>
<td>70° A</td>
</tr>
<tr>
<td>9</td>
<td>70° CA+60° B</td>
<td>70° A B</td>
<td>60° A+70° GB</td>
</tr>
</tbody>
</table>

#### LEGEND

- **X** — Check from Face “C”
- **G** — Grind Weld Face Flush
- **O** — Not Required
- **F** — Further evaluate fusion zone indications with either 70°, 60° or 45° transducer whichever sound path is nearest to being perpendicular to the suspected fusion surface.
- **+** — Required only where reference level indication of defect is noted in fusion zone while searching at scanning level with primary procedure selected from first column.
- **** — Use 15 or 20 inch screen distance calibration (the smaller value) as necessary to permit testing of the complete weld and adjacent heat-affected zones using the search unit required by the Procedure Legend.
- **RT** — Radiographic Inspection
- **I** — Examine weld in Node I
- **II** — Examine weld in Node II
- **“A” Face** — The face of the material from which the initial scanning is done (on Tees and Corners follow above sketches)
- **“B” Face** — Opposite the “A” Face (same plate).
TABLE 700A (continued)

NOTES:

1. All examinations are to be made from Face "A" except as noted in the Procedure Chart (Table 700A) and scanned from both sides of the weld on Face "A" or Face "A" and Face "B" as indicated, where mechanically possible.

2. All examinations are to be made in Node I where possible, or Node II when necessary to test weld areas at a sound path of one inch or greater from the angle beam search unit. A maximum of Node III may be used when approved by the D.C.E.S.

3. Face "A" on both connecting members at a butt weld must lie in a single plane. Should neither Face "A" nor Face "B" of a Butt Weld lie in a single plane, the testing procedure will be subject to the approval of the D.C.E.S.

EXAMPLE:    BUTT WELD IN 4" MATERIAL
             NO. 4 PROCEDURE

```
FACE "A"

TOP QUARTER - 60°B
MIDDLE HALF - 70°A
BOTTOM QUARTER - 60°A

FACE "B"
```

```text
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
1.10
1.11
1.12
1.13
1.14
1.15
1.16
1.17
1.18
1.19
1.20
1.21
1.22
1.23
1.24
1.25
1.26
1.27
1.28
1.29
1.30
1.31
1.32
1.33
1.34
1.35
1.36
1.37
1.38
1.39
1.40
```
### TABLE 700B – HIGHWAY AND RAILWAY BRIDGES

#### MINIMUM ACCEPTANCE LEVELS (DECIBELS)

<table>
<thead>
<tr>
<th>REFLECTOR SEVERITY</th>
<th>Weld Thickness and Transducer Angle</th>
<th>( \leq \frac{3}{8} )</th>
<th>( \frac{3}{8} ) to ( \frac{1}{2} )</th>
<th>( \frac{1}{2} ) to 2%</th>
<th>( &gt; 2% ) to 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( 70^\circ )</td>
<td>( 70^\circ )</td>
<td>( 70^\circ )</td>
<td>60° *</td>
<td>45° *</td>
</tr>
<tr>
<td>Large Reflectors</td>
<td>+14</td>
<td>+9</td>
<td>+8</td>
<td>+9</td>
<td>+11</td>
</tr>
<tr>
<td>Small Reflectors</td>
<td>+19</td>
<td>+10</td>
<td>+8</td>
<td>+11</td>
<td>+13</td>
</tr>
<tr>
<td>Minor Reflectors</td>
<td>+16</td>
<td>+11</td>
<td>+10</td>
<td>+13</td>
<td>+15</td>
</tr>
</tbody>
</table>

#### LARGE REFLECTORS:

Any discontinuity, regardless of length having a more serious rating (smaller number) than this level shall be rejected.

#### SMALL REFLECTORS:

Any discontinuity longer than \( \frac{3}{8} \)" having a more serious rating (smaller number) than this level shall be rejected.

#### MINOR REFLECTORS:

Only those discontinuities exceeding 2" in length and having a more serious rating (smaller number) than this level shall be rejected.

#### NOTES:

1. Discontinuities which have a more serious rating than those of “Minor Reflectors,” shall be separated by at least 2L, L being the length of the larger discontinuity. Discontinuities not separated by at least 2L are considered to be one continuous discontinuity whose length is determined by the combined length of the discontinuities plus their separation distance.

2. Discontinuities which have a more serious rating that those of “Minor Reflectors” shall not begin at a distance smaller than 2L from the end of the weld or from any intersecting weld, L being the discontinuity length.

3. Discontinuities in the root-land area of full penetration double Vee, double “J” and double “U” welds detected at “Scanning Level” shall be evaluated at an acceptance level 4 db. more sensitive than prescribed by this table; i.e., add plus four units to the number in the table.

4. Discontinuities which have a more serious rating than those of “Minor Reflectors” and which exceed \( \frac{3}{8} \)" in length are permitted only in the middle half of the weld thickness.

*Flaws evaluated with 60° or 45° search units and rejected at the acceptance levels listed in the table, but which are acceptable at the minimum acceptance level listed for a 70° transducer shall also be evaluated with a 70° search unit. If detailed testing reveals that the sound beam of the 60° or 45° search unit is striking the flaw at 90° ± 10°, the acceptance level listed for a 70° transducer shall be used as the basis for acceptance, regardless of the angle of the search unit used to evaluate the flaw.

#### SCANNING LEVELS

<table>
<thead>
<tr>
<th>Distance</th>
<th>Above Zero Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>to 2%&quot;</td>
<td>+20 db</td>
</tr>
<tr>
<td>( &gt; 2% - 6% )&quot;</td>
<td>+25 db</td>
</tr>
<tr>
<td>( &gt; 6 - 10% )&quot;</td>
<td>+35 db</td>
</tr>
<tr>
<td>( &gt; 10 - 15% )&quot;</td>
<td>+45 db</td>
</tr>
<tr>
<td>( &gt; 15 - 20% )&quot;</td>
<td>+55 db</td>
</tr>
</tbody>
</table>
TABLE 700C – BUILDINGS

<table>
<thead>
<tr>
<th>REFLECTOR SEVERITY</th>
<th>MINIMUM ACCEPTANCE LEVELS (DECIBELS)</th>
<th>5/16 to 3/4</th>
<th>3/4 to 1½</th>
<th>1½ to 2¼</th>
<th>2¼ to 3</th>
<th>3/4 to 1½</th>
<th>1½ to 2¼</th>
<th>2¼ to 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weld Thickness and Transducer Angle</td>
<td>70°</td>
<td>70°</td>
<td>70°</td>
<td>60°*</td>
<td>45°*</td>
<td>70°</td>
<td>60°*</td>
<td>45°*</td>
</tr>
<tr>
<td>Large Reflectors</td>
<td>-8</td>
<td>+3</td>
<td>0</td>
<td>+3</td>
<td>+5</td>
<td>-2</td>
<td>+1</td>
<td>+3</td>
</tr>
<tr>
<td>Small Reflectors</td>
<td>+9</td>
<td>+4</td>
<td>-2</td>
<td>+5</td>
<td>+7</td>
<td>0</td>
<td>+3</td>
<td>+8</td>
</tr>
<tr>
<td>Minor Reflectors</td>
<td>+10</td>
<td>+5</td>
<td>+7</td>
<td>+9</td>
<td>+2</td>
<td>+5</td>
<td>+17</td>
<td></td>
</tr>
</tbody>
</table>

LARGE REFLECTORS:

Any discontinuity, regardless of length having a more serious rating (smaller number) than this level shall be rejected.

SMALL REFLECTORS:

Any discontinuity longer than \( \frac{3}{4}'' \) having a more serious rating (smaller number) than this level shall be rejected.

MINOR REFLECTORS:

Only those discontinuities exceeding 2'' in length and having a more serious rating (smaller number) than this level shall be rejected.

NOTES:

1. Discontinuities which have a more serious rating than those of “Minor Reflectors,” shall be separated by at least 2L, L being the length of the larger discontinuity. Discontinuities not separated by at least 2L are considered to be one continuous discontinuity whose length is determined by the combined length of the discontinuities plus their separation distance.

2. Discontinuities which have a more serious rating than those of “Minor Reflectors” shall not begin at a distance less than 2L from weld ends carrying primary tensile stress, L being the discontinuity length.

3. Discontinuities in the root-land area of full penetration double Vee, double “J” and double “U” welds detected at “Scanning Level” shall be evaluated at an acceptance level 4 db. more sensitive than prescribed by this table; i.e., add plus four units to the number in the table.

*Flaws evaluated with 60° or 45° search units and rejected at the acceptance levels listed in the table, but which are acceptable at the minimum acceptance level listed for a 70° transducer shall also be evaluated with a 70° search unit. If detailed testing reveals that the sound beam of the 60° or 45° search unit is striking the flaw at 90° ±10°, the acceptance level listed for a 70° transducer shall be used as the basis for acceptance, regardless of the angle of the search unit used to evaluate the flaw.
SECTION VIII
MAGNETIC PARTICLE INSPECTION

801. GENERAL. The procedures and standards set forth in this section shall be followed whenever magnetic particle inspection is required by the Contract Documents or ordered by the Engineer under the provisions of these Specifications. All magnetic particle inspection performed by State forces, Inspection Agencies under contract to the State, Contractors or their agents shall conform to the requirements of this Specification. Variations in testing procedures or equipment shall be subject to approval by the D.C.E.S.

802. TESTING PROCEDURES AND EQUIPMENT. All testing shall be performed in accordance with the provisions of ASTM Designation E109, Standard Method for Dry Powder Magnetic Particle Inspection, except as modified herein.

802.1. Current. The magnetizing source shall produce rectified half wave direct current. The minimum magnetizing current shall be 400 amperes and shall be not less than 100 amperes per inch of prod spacing. Higher testing currents approaching a current density of 150 amperes per inch of prod spacing are preferred. Arcing must be controlled by proper testing techniques.

802.2. Prod Positioning. The prods shall be oriented in two directions approximately 90 degrees apart at each inspection point, to detect both longitudinal and transverse discontinuities. The prod positions shall overlap as the testing progresses to insure 100% inspection of the areas to be tested.

802.3. Surface Condition. The surface being inspected shall be clean and dry and free of oil, rust, loose mill scale and paint. Grinding may be required to provide proper electrical contact and to remove surface irregularities that interfere with interpretation of test indications.

802.4. Special Equipment. Wherever magnetic particle inspection is performed on ASTM A588 Steel or any steel with a minimum specified yield stress exceeding 50 ksi, aluminum prods shall be used on the test equipment. The use of copper prods will not be permitted on such steels.

803. WITNESSING OF MAGNETIC PARTICLE TESTS. All magnetic particle inspection that is not performed by State forces or an inspection agency under contract to the State shall be witnessed by a representative of the State.

804. PREPARATION AND DISPOSITION OF REPORTS. A test report shall be prepared for each erection piece subject to inspection. The report shall be prepared by the technician performing the test. The report shall contain sufficient information to identify the extent of the weld or base metal inspected, the name of the technician (signature), and the name of the State representative witnessing the work, if required by Paragraph 803. All indications of discontinuities shall be recorded in the test report. The Contract and date of test shall be listed on each report together with the Fabricator’s Shop Order Number and the Erection Mark on the piece.

A complete set of test reports shall be delivered to the D.C.E.S. upon completion of the work.

805. STANDARDS OF ACCEPTANCE. Welds subject to magnetic particle inspection shall have no cracks. Porosity and fusion-type defects shall be evaluated in accordance with the provisions of Sections 615.1, 615.2 or 615.3 as applicable.
SECTION IX

DYE PENETRANT INSPECTION

901. GENERAL. The procedures and standards set forth in this section shall be used whenever dye penetrant inspection is required by the Contract Documents or ordered by the Engineer under the provisions of these Specifications. This inspection method is limited to the detection of discontinuities that are open to the surface. Penetrant tests shall only be performed when the steel is between the temperatures of 40 degrees F to 110 degrees F.

902. TESTING PROCEDURES. All testing shall be performed in accordance with the provisions of ASTM Designation E165. The visible dye penetrant method shall be used.

The surface being inspected shall be cleaned in accordance with ASTM Designation E165. Surface irregularities that interfere with the interpretation of test results shall be removed by grinding. All welds shall be smoothed by grinding prior to testing.

903. WITNESSING OF DYE PENETRANT TESTS. All dye penetrant inspection that is not performed by State employees or an inspection agency under contract to the State shall be witnessed by a representative of the State.

904. PREPARATION AND DISPOSITION OF REPORTS. A test report shall be prepared for each erection piece subject to inspection. The report shall be prepared by the technician performing the test. The report shall contain sufficient information to identify the extent of the weld or base metal inspected, the name of the technician (signature), and the name of the State representative witnessing the work, if required by Paragraph 903. All indications of discontinuities shall be recorded in the test report. The Contract number and date of test shall be listed on each report together with the Fabricator's Shop Order Number and the Erection Mark on the piece.

A complete set of test reports shall be delivered to the D.C.E.S. upon completion of the work.

905. STANDARDS OF ACCEPTANCE. Welds subject to dye penetrant inspection shall have no cracks. Porosity and fusion-type defects shall be evaluated in accordance with the provisions of Section 615.1, 615.2, or 615.3 as applicable.
# APPENDIX A

**Flatness of Girder Webs**

![Diagram of girder web with labels](image)

- **D** = depth of web
- **d** = least panel dimension

| Thickness of Web | Depth of Web | INTERIOR GIRDER
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16, 47 and Over</td>
<td></td>
<td>Least Panel Dimensions</td>
</tr>
<tr>
<td>3/8, 56 and Over</td>
<td></td>
<td>29 36 43 50</td>
</tr>
<tr>
<td>7/16, 66 and Over</td>
<td></td>
<td>29 36 43 50 58 63 69 75 81 86 92 98</td>
</tr>
<tr>
<td>1/2, 75 and Over</td>
<td></td>
<td>29 36 43 50 58 63 69 75 81 86 92 98</td>
</tr>
<tr>
<td>9/16, 84 and Over</td>
<td></td>
<td>29 36 43 50 58 63 69 75 81 86 92 98</td>
</tr>
<tr>
<td>5/8, 94 and Over</td>
<td></td>
<td>29 36 43 50 58 63 69 75 81 86 92 98</td>
</tr>
</tbody>
</table>

**NOTES:**

1. All dimensions are in inches.
2. For actual dimensions not shown, use the next highest figure.

**INTERMEDIATE STIFFENERS ON BOTH SIDES OF WEB**

<table>
<thead>
<tr>
<th>Thickness of Web</th>
<th>Depth of Web</th>
<th>LEAST PANEL DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4</td>
<td>5/16</td>
<td>3/8</td>
</tr>
<tr>
<td>7/16</td>
<td>1/2</td>
<td>9/16</td>
</tr>
<tr>
<td>11/16</td>
<td>3/4</td>
<td>13/16</td>
</tr>
<tr>
<td>15/16</td>
<td>1</td>
<td>1-1/16</td>
</tr>
</tbody>
</table>
## INTERMEDIATE STIFFENERS ON BOTH SIDES OF WEB

<table>
<thead>
<tr>
<th>Thick. of Web</th>
<th>Depth of Web</th>
<th>FASCIA GIRDERS</th>
<th>LEAST PANEL DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>Less than 47 47 and Over</td>
<td>33 41 49</td>
<td>26 33 39 46 53 59 66 72 79 85 92 98 105 112</td>
</tr>
<tr>
<td></td>
<td>3/8 Less than 56 56 and Over</td>
<td>33 41 49 57</td>
<td>26 33 39 46 53 59 66 72 79 85 92 98 105 112</td>
</tr>
<tr>
<td></td>
<td>7/16 Less than 66 66 and Over</td>
<td>33 41 49 57 65 73</td>
<td>26 33 39 47 53 59 66 72 79 85 92 98 105 112</td>
</tr>
<tr>
<td></td>
<td>1/2 Less than 75 75 and Over</td>
<td>33 41 49 57 65 73 81</td>
<td>26 33 39 47 53 59 66 72 79 85 92 98 105 112</td>
</tr>
<tr>
<td></td>
<td>9/16 Less than 84 84 and Over</td>
<td>33 41 49 57 65 73 81 89</td>
<td>26 33 39 47 53 59 66 72 79 85 92 98 105 112</td>
</tr>
<tr>
<td></td>
<td>5/8 Less than 94 94 and Over</td>
<td>33 41 49 57 65 73 81 89 98</td>
<td>26 33 39 47 53 59 66 72 79 85 92 98 105 112</td>
</tr>
</tbody>
</table>

**MAXIMUM DEVIATION**

1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 1 1-1/16

## INTERMEDIATE STIFFENERS ON ONE SIDE ONLY OF WEB

<table>
<thead>
<tr>
<th>Thick. of Web</th>
<th>Depth of Web</th>
<th>INTERIOR GIRDERS</th>
<th>LEAST PANEL DIMENSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>Less than 31 31 and Over</td>
<td>25 31</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
<tr>
<td></td>
<td>3/8 Less than 38 38 and Over</td>
<td>25 31 38</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
<tr>
<td></td>
<td>7/16 Less than 44 44 and Over</td>
<td>25 31 38 44</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
<tr>
<td></td>
<td>1/2 Less than 50 50 and Over</td>
<td>25 31 38 44 50</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
<tr>
<td></td>
<td>9/16 Less than 56 56 and Over</td>
<td>25 31 38 44 50 56</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
<tr>
<td></td>
<td>5/8 Less than 63 63 and Over</td>
<td>25 31 38 44 50 56 63</td>
<td>17 21 25 29 34 38 42 46 50 54 59 63 67 71</td>
</tr>
</tbody>
</table>

**MAXIMUM DEVIATION**

1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 1 1-1/16
### INTERMEDIATE STIFFENERS ON ONE SIDE ONLY OF WEB

<table>
<thead>
<tr>
<th>Thick. of Web</th>
<th>Depth of Web</th>
<th>Fascia Girders</th>
<th>Least Panel Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/16</td>
<td>Less than 31</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>31 and Over</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>3/8</td>
<td>Less than 38</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>38 and Over</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>7/16</td>
<td>Less than 44</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>44 and Over</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>1/2</td>
<td>Less than 50</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>50 and Over</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>9/16</td>
<td>Less than 56</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>56 and Over</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>5/8</td>
<td>Less than 63</td>
<td>30</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>63 and Over</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

**Maximum Deviation**

1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 1 1-1/16

### NO INTERMEDIATE STIFFENERS

<table>
<thead>
<tr>
<th>Thich. of Web</th>
<th>Depth of Web</th>
<th>Interior or Fascia Girder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Maximum Deviation**

1/4 5/16 3/8 7/16 1/2 9/16 5/8 11/16 3/4 13/16 7/8 15/16 1 1-1/16 1-1/8 1-3/16 1-1/4
APPENDIX B
Terms and Definitions

A

All-Weld-Metal Test Specimen: A test specimen wherein the portion being tested is composed wholly of weld metal.

Air-Arc Gouging, Arc-Air Gouging or Air-Carbon-Arc Gouging: A process for metal removal where the metal is melted by an electric arc and blown clear of the removal area by compressed air. Inert gas may be approved by D.C.E.S. for special applications where compressed air is not readily available.

Amplitude (U.T.): The vertical height of the trace deflection on the cathode ray tube of the ultrasonic flaw detector.

Amplitude Length Rejection Level (U.T.): The length of defect permitted for various “Decibel Ratings” as associated with throat thickness, as indicated in Tables 700B and 700C.

Angle of Bevel: See preferred term Bevel Angle.

As-Welded: The condition of weld metal, welded joints, and weldments after welding prior to any subsequent aging, thermal, mechanical or chemical treatments.

Attenuation (U.T.): The absorption of sound energy by the test material. In the ultrasonic test method of inspection specified by this manual the attenuation factor is at the rate of 2 db per inch of sound travel after the first inch. (Use this number as “Attenuation Factor”, “c”, on the form shown in Fig. 700F.)

Also, in radiography, the absorption of photons by the test material. This absorption is dependent upon the material thickness, density and atomic nature.

Automatic Welding: Welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by a welding operator. The equipment may or may not perform the loading and unloading of the work. See Machine Welding.

Axis of a Weld: A line through the length of a weld, perpendicular to the cross section at its center of gravity.

B

Back Gouging: The forming of a bevel or groove on the other side of a partially welded joint to assure complete joint penetration upon subsequent welding from that side.

Backing: Metal or weld metal backing up the joint during welding.

Backing Pass: A pass made to deposit a backing weld.

Backing Ring: Backing in the form of a ring, generally used in the welding of piping.

Backing Strip: Backing in the form of a strip.

Backing Weld: Backing in the form of a weld.

Back Weld: A weld deposited at the back of a single-groove weld.

Base Metal: The metal to be welded or cut.

Bevel Angle: The angle formed between the prepared edge of a member and a plane perpendicular to the surface of the member.

Beveling: The operation of continuing a fillet weld around a corner of a member as an extension of the principal weld.

Butt Joint: A joint between two members lying approximately in the same plane.

Butt Weld: A weld in a butt joint.

C

Complete Fusion: Fusion which has occurred over the entire base-metal surfaces exposed for welding, and between all layers and passes.

Complete Joint Penetration Groove Weld (Buildings and Bridges): A groove weld which has been made from both sides or from one side on a backing having complete penetration and fusion of weld and base metal throughout the depth of the joint.

Complete Joint Penetration: Joint penetration which extends completely through the joint.

Complete Penetration: See preferred term Complete Joint Penetration.

Consumable Guide Electroslag Welding: See Electroslag Welding.

Continuous Weld: A weld which extends continuously from one end of a joint to the other. Where the joint is essentially circular, it extends completely around the joint.

Corner Joint: A joint between two members located approximately at right angles to each other in the form of an L.

CO₂ Welding: See preferred term Flux Cored Arc Welding with External Shielding Gas.

Couplant (U.T.): A material (see Article 708.3 for allowable couplants) used between the face of the ultrasonic search unit (transducer) and the test surface to permit or improve the transmission of the ultrasound between the search unit and the material under test.
Crater: In arc welding a depression at the termination of a weld bead or in the weld pool beneath the electrode.

D

Decibel (U.T.): A measurable unit of sound amplitude.

Decibel Rating (db) (U.T.): A value of amplitude of signal varying up or down from the standard reference gain setting, and corrected for distance attenuation. See 710.6 and Fig. 700F.

Defect: A weld or base metal discontinuity discovered and evaluated by visual or nondestructive tests that is of rejectable size.

Defect Level (U.T.): The calibrated gain control or attenuation control reading obtained from a discontinuity.

Defect Rating (U.T.): The decibel reading in relation to the zero reference level after being corrected for attenuation. See 710.6 and Fig. 700F.

Discontinuity: Any internal or surface interruption of the continuity of the metal. This includes porosity, cracks, slag inclusions, inclusions of other metals or nonmetals, incomplete fusion, undercut, laminations and any other phenomenon or material that interrupts the metal. Minor changes in microstructure are not included.

Depth of Fusion: The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

Downhand: See preferred term Flat Position.

E

Effective Length of Weld: The length of weld throughout which the correctly proportioned cross section exists. In a curved weld, it shall be measured along the centerline of the throat.

Electrogas Welding: A method of Gas Metal-Arc Welding or Flux Cored Arc Welding with Carbon Dioxide Shielding wherein molding shoes confine the molten weld metal for vertical position welding.

Electroslag Welding (EW): A welding process wherein coalescence is produced by molten slag which melts the filler metal and the surfaces of the work to be welded. The weld pool is shielded by this slag which moves along the full cross section of the joint as welding progresses. The conductive slag is maintained molten by its resistance to electric current passing between the electrode and the work. Consumable Guide Electroslag Welding - A method of electroslag welding wherein filler metal is supplied by a electrode and its guiding member.

F

Faying Surface: That surface of a member which is in contact or in close proximity with another member to which it is to be joined.

Filler Metal: The metal to be added in making a welded, brazed, or soldered joint. See Electrode, Welding Rod and Backing Filler Metal in AWS A3.0.

Flat Position: The position of welding wherein welding is performed from the upper side of the joint and the face of the weld is approximately horizontal.

Flux Cored Arc Welding with External Shielding Gas (FCAW): An arc welding process wherein coalescence is produced by heating with an arc, between a continuous filler metal (consumable) electrode and the work. Shielding is obtained from a flux contained within the electrode and from an externally supplied carbon dioxide gas or gas mixture.

Full Penetration Groove Weld: See Complete Joint Penetration Groove Weld.

Fusion-type Defect (Also referred to as Fusion Defect): Signifies slag inclusions, incomplete fusion, inadequate penetration and similar generally elongated defects in weld fusion.

Fusion: The melting together of filler metal and base metal which results in coalescence. See Depth of Fusion.

Fusion Boundary: The interface between the weld metal (consisting of filler metal and melted base metal) and the unmelted base metal as observed visually or by metallurgical tests.

Fusion Zone: The area of base metal melted as determined on the cross section of a weld.

G

Gas Pocket: A cavity caused by entrapped gas.

Gouging: The forming of a bevel or groove by material removal. See also Back Gouging and Air-Arc Gouging.

Groove Angle: The total included angle of the groove between parts to be joined by a groove weld.

Groove Face: That surface of a member included in the groove.

Groove Weld: A weld made in the groove between two members to be joined.

H

H&D Density: (Hurter & Driffield Density) A method for measuring the degree of exposure of radiographs. The density is equal to the logarithm of the ratio of the light intensity incident on the film to the light intensity transmitted.
Heat-Affected Zone: That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding or cutting.

Heat-Shrink: A procedure for curving, straightening or cambering plates, beams, girders and other pieces or fabricated members by the controlled application of heat to specific locations in the piece. The dimensional change of the material results from the upset shortening of the steel in the heated areas.

Horizontal Position: Fillet Weld — The position of welding wherein welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface. See Figs. 401.3.b and 402.7.

Groove Weld — The position of welding wherein the axis of the weld lies in an approximately horizontal plane and the face of the weld lies in an approximately vertical plane. See Figs. 401.3.a and 401.3.1.

Horizontal Reference Line (U.T.): A horizontal line near the center of the ultrasonic test instrument scope to which all echoes are adjusted for dB reading.

Incomplete Fusion: The failure to fuse together adjacent layers of weld metal or adjacent weld metal and base metal. This failure to obtain fusion may occur at any location in the weld deposit. This type of defect can result from:

a. Failure to raise the surface of the metal adjacent to the weld metal being deposited to its melting temperature through improper manipulation of the heat source.

b. Failure to remove mill scale, oxides, or other foreign material from the surfaces to which the deposited weld metal must fuse.

c. Failure to remove all traces of slag formed during the deposition of a previous weld bead. In such cases, where slag particles or films of slag are entrapped at the interface, the defect is called a “slag inclusion” but it nonetheless is a region exhibiting lack of fusion.

Intermittent Weld: A weld wherein the continuity of the weld is broken by recurring unwelded spaces.

Interpass Temperature: In a multiple-pass weld, the temperature (minimum or maximum as specified) of the deposited weld metal and adjacent base metal before the next pass is started.

Joint: The location where two or more members are to be joined.

Joint Penetration: The minimum depth a groove weld extends from its face into a joint, exclusive of reinforcement.

Joint Welding Procedure: The materials, detailed methods and practices employed in the welding of a particular joint.

Lack of Fusion: See Incomplete Fusion.

Lamellar Tearing: A terrace-like separation in base metal generally caused by thermally induced shrinkage stresses from welding acting in the through-thickness direction in wrought materials. The fracture, which may extend over long distances in a direction roughly parallel to the rolled surface, generally initiates in regions of the base metal having a high incidence of coplanar stringer-like nonmetallic inclusions. The fracture usually propagates from one lamellar plane to another by shear along a surface oriented at roughly 45° to the rolled surface.

Lap Joint: A joint between two overlapping members.

Layer: A stratum of weld metal, consisting of one or more weld beads.

Leg of a Fillet Weld: The distance from the root of the joint to the toe of the fillet weld.

Longitudinal Weld Discontinuity: A weld discontinuity whose major dimension is in a direction parallel to the weld axis “X”, Fig. 700F.

Machine Welding: Welding with equipment which performs the welding operation under the constant observation and control of an operator. The equipment may or may not perform the loading and unloading of the work. See Automatic Welding.

Manual Welding: Welding wherein the entire welding operation is performed and controlled by hand. See Automatic Welding and Machine Welding.


Node (U. T.): The distance the shear wave travels in a straight line before being reflected by the surface of the material being testing. See sketch below for node identification.

Overhead Position: The position of welding wherein welding is performed from the underside of the joint. See Figs. 401.3, 401.3.1 and 402.7.
Overlap: Protrusion of weld metal beyond the toe or root of the weld. A notch defect resulting from excessive convexity (See Fig. 203.17) and failure to fuse at the toe of the weld.

Oxygen Cutting (OC): A group of cutting processes wherein the severing or removing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures.

In the case of oxygen-resistant metals the reaction is facilitated by the use of a chemical flux or metal powder. See Oxygen-Arc Cutting, Oxy-Fuel Gas Cutting, Oxygen-Lance Cutting, Chemical Flux Cutting, and Metal Powder Cutting in AWS A3.6.

P

Partial Joint Penetration Groove Weld: A groove weld welded from one or both sides and having joint penetration which is less than complete.

Pass: A single longitudinal progression of welding operation along a joint or weld deposit. The result of a pass is a weld bead.

Peening: The mechanical working of metals by means of impact blows.

Penetrometer: A radiographic quality indicator. See Sub-section 607 for a description of the penetrometers required.

Piping Porosity: Pitholes that are included in a plane passing through the root of a weld approximately normal to the weld surface whose depths are greater than their diameter.

Plug Weld: A circular weld made through a hole in one member of a lap or tee joint joining that member to the other. The walls of the hole may or may not be parallel and the hole may be partially or completely filled with weld metal. (A fillet-welded hole or a spot weld should not be construed as conforming to this definition.)

Porosity: Gas pockets and any similar generally globular type voids.

Positioned Weld: A weld made in a joint which has been so placed as to facilitate making the weld.

Postheating: The application of heat to an assembly after a welding or cutting operation.

Preheating: The application of heat to the base metal immediately before welding or cutting.

Preheat Temperature: The temperature specified that the base metal must attain in the welding or cutting area immediately before these operations are performed.

Procedure Qualification: The demonstration that welds made by a specific procedure can meet prescribed standards.

Q

Qualification: See preferred terms, Welder Qualification and Procedure Qualification.

R

Random Sequence: See preferred term Wandering Sequence.


Reference Reflector (U.T.): The standard reflector contained in the I1W reference block or other approved blocks.

Reinforcement of Weld: Weld metal in excess of the specified weld throat (See Fig. 203.17).

Rejectable Discontinuity (Defect) (U.T.): A reflector of sufficient size to produce a signal (Decibel Rating) equal to or greater than the "Reject" values specified in Table 700A. See also Sections 600, 800 and 900 for limits of rejectable discontinuities discovered by other non-destructive test methods. Any discontinuity or weld flaw not permitted under the weld quality requirements of the specifications. See Article 203.18 for Bridges and Article 203.19 for Buildings.

Resolution (U.T.): The ability to distinguish separate trace deflections from closely spaced reflecting surfaces.

Root Face: That portion of the groove face adjacent to the root of the joint.

Root Gap: See preferred term Root Opening.

Root of Joint: That portion of a joint to be welded where the members approach closest to each other. In cross section the root of the joint may be either a point, a line or an area.

Root of Weld: The points, as shown in cross section, at which the back of the weld intersects the base metal surfaces.

Root Opening: The separation between the members to be joined at the root of the joint.

S

Scanning Level (U.T.) The db setting during scanning as described in Tables 700 B & C.

Semiautomatic Arc Welding: Arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

Shielded Metal Arc Welding (SMAW): An Arc-welding process wherein coalescence is produced by heating with an arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.
Size of Weld:

Groove Weld — The joint penetration (depth of chamfering plus the root penetration when specified).

Fillet Weld — For equal leg fillet welds, the leg length of the largest isosceles right-triangle which can be inscribed within the fillet-weld cross section.

Slag Inclusion: Oxides and other nonmetallic solids entrapped in weld metal or between weld metal and base metal. Slag inclusions generally result from the failure to remove the slag between beads and layers of multipass welds, from improper manipulation of the electrode or from failure to provide a proper contour on which each weld bead is deposited.

Slot Weld: A weld made in an elongated hole in one member of a lap or tee joint joining that member to the other portion of the surface of the other member which is exposed through the hole. The hole may be open at one end and may be partially or completely filled with weld metal (A fillet-welded slot should not be construed as conforming to this definition.)

Sound Beam Distance (U.T.): The distance between the search unit sound index point at the steel interface and the reflector (as calibrated).

Spatter: In arc and gas welding, the metal particles expelled during welding and which do not form a part of the weld.

Stringer Bend: A type of weld bead made without appreciable transverse oscillation.

Stud Base: The stud tip at the welding end, including flux and container, and 1/8 in. of the body of the stud adjacent to the tip.

Stud Welding (SW): An arc-welding process wherein coalescence is produced by heating with an arc drawn between a metal stud, or similar part, and the other work part until the surfaces of the stud are properly heated, when they are brought together under pressure. Partial shielding may be obtained by the use of a ceramic ferrule surrounding the stud. Shielding gas or flux may or may not be used.

Submerged Arc Welding (SAW): An arc-welding process wherein coalescence is produced by heating with an arc or arcs between a bare metal electrode or electrodes and the work. The arc is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

a. Single electrodes — means one electrode connected exclusively to one power source which may consist of one or more power units.
b. Parallel electrode — means two electrodes connected electrically in parallel exclusively to the same power source. Both electrodes are usually fed by means of a single electrode feeder. Welding current, when specified, is the total for the two electrodes.

c. Tandem Electrode — refers to the geometrical arrangement of the electrodes in which a line through the arcs is parallel to the direction of welding. Separate power sources are used for each electrode. It is common to use direct current reverse polarity in the lead electrode and alternating current in the following electrode.

T

Tack Weld: A weld made to hold parts of a weldment in proper alignment until the final welds are made.

Tacker: One who, under the direction of a fitter, or is a fitter, tack welds parts of a weldment to hold them in proper alignment until the final welds are made.

Tee Joint: A joint between two members located approximately at right angles to each other in the form of a T.

Temporary Weld: A weld made to attach a piece or pieces to a weldment for temporary use in handling, shipping or working on the weldment.

Throat of a fillet weld:

Theoretical — The distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right-triangle which can be inscribed within the fillet-weld cross section.

Actual — The shortest distance from the root of a fillet weld to its face.

Throat of a Groove Weld: See preferred term Size of Weld.

Toe of Weld: The junction between the face of a weld and the base metal.

Transverse Discontinuity: A weld discontinuity whose major dimension is in a direction perpendicular to the weld axis "X", Fig. 700F.

Undercut: A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Vertical Position: The position of welding wherein the axis of the weld is approximately vertical. See Figs. 401.3, 401.3.1 and 402.7.

Wandering Sequence: A longitudinal sequence wherein the weld bead increments are deposited at random.

Weave Bead: A type of weld bead made with transverse oscillation.
Weld: A localized coalescence of metal wherein coalescence is produced either by heating to suitable temperatures, with or without the application of pressure, or by the application of pressure alone, and with or without the use of filler metal. The filler metal either has a melting point approximately the same as the base metals or has a melting point below that of the base metals but above 800°F (427°C).

Weld Bead: A weld deposit resulting from a pass. See Stringer Bead and Weave Bead.

Weldability: The capacity of a metal to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service.

Welder: One who is capable of performing a manual or semiautomatic welding operation. (Sometimes erroneously used to denote a welding machine.)

Welder Certification: Certification in writing that a welder has produced welds meeting prescribed standards.

Welder Qualification: The demonstration of a welder's ability to produce welds meeting prescribed standards.

Welding (Noun): The metal joining process used in making welds. (See the Master Chart of Welding Processes, AWS A3.1)

Welding Machine: Equipment used to perform the welding operation. For example, spot-welding machine, arc-welding machine, seam-welding machine, etc.

Welding Operator: One who operates machine or automatic welding equipment.

Welding Procedure: The detailed methods and practices including all joint welding procedures in the production of a weldment. See Joint Welding Procedure.

Welding Sequence: The order of making the welds in a weldment.

Weldment: An assembly whose component parts are joined by welding.