A PROPOSED FRACTURE CONTROL PLAN FOR NEW BRIDGES with FRACTURE CRITICAL MEMBERS

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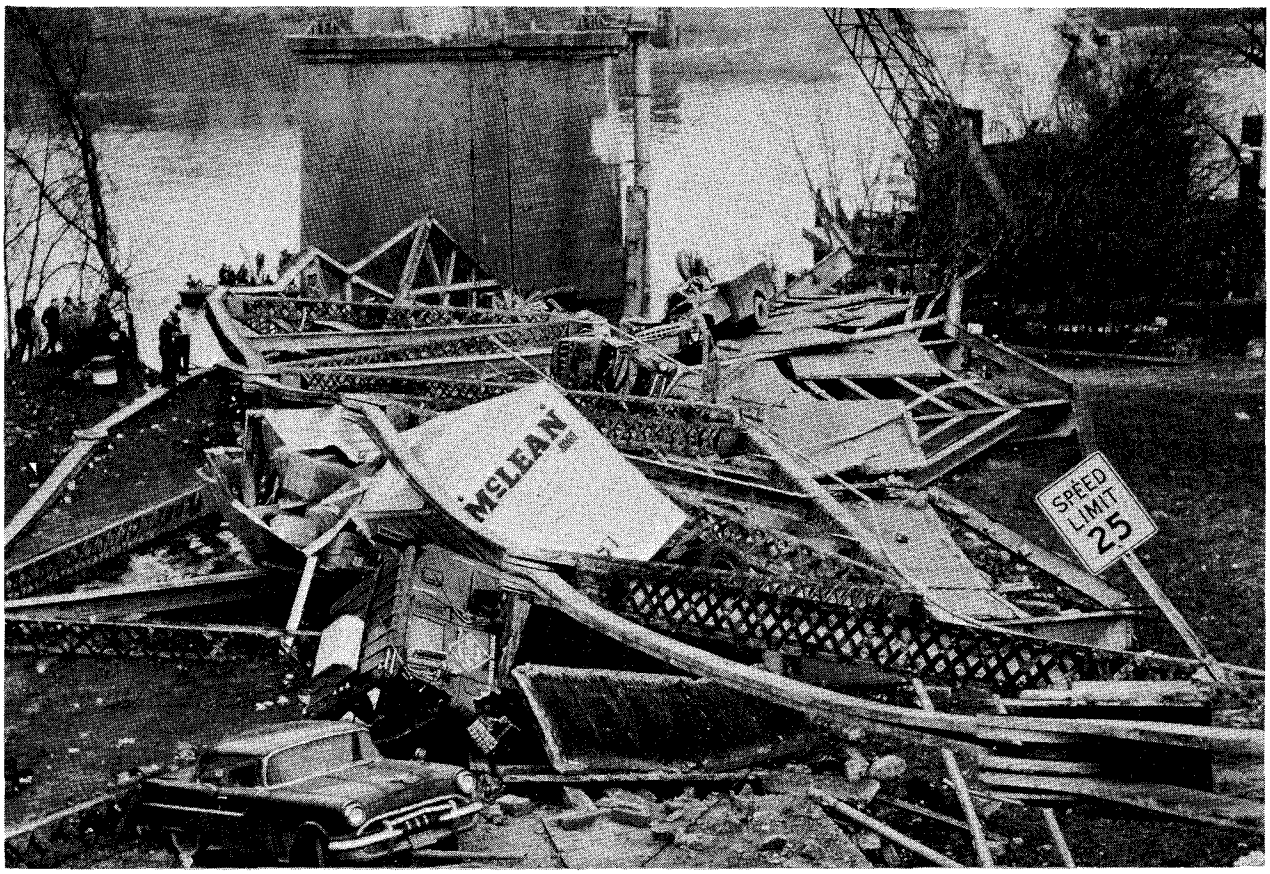

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A PROPOSED
FRACTURE CONTROL PLAN FOR NEW BRIDGES
with
FRACTURE CRITICAL MEMBERS

by
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Volume II

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PREFACE

The following Special Provisions for "fracture-critical members constitute a modification of the following publications:

(1) the American Welding Society (AWS) Structural Welding Code AWS D1.1-Rev. 2-77,

(2) the American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Welding of Structural Steel Highway Bridges, Second Edition, 1977,

(3) the AASHTO Standard Specifications for Highway Bridges, 12th Edition, 1977,

(4) the AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 1, Specifications, 11th Edition, 1974.

The modifications as enumerated in the following fracture control plan shall supersede the above documents. With the exception of Section 1 - General Provisions, the paragraph, table and figure numbers used herein correspond to the numbers in AWS D1.1-75 as amended. Section 9 - Design of New Bridges of AWS D1.1 has been deleted and those provisions formerly in Section 9 deemed revelant to FCMs have been incorporated in the appropriate sections of this code.

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TABLES

FIGURES

FRACTURE-CONTROL PLAN

1. GENERAL PROVISIONS

1.1 SCOPE. This fracture control plan:

1.1.1 assigns responsibility for specifying which, if any, steel structural components fall in the category of "fracture-critical";

1.1.2 requires American Institute of Steel Construction (AISC) Quality Certification, or other suitable certification of the fabricator to assure that structures containing "fracture-critical" members are fabricated by plants with personnel, organization, experience, procedures, knowledge, and equipment capable of producing quality workmanship;

1.1.3 requires that all Welding Inspectors be qualified under the provisions of the American Welding Society (AWS) Qualification and Certification Program, or other suitable demonstration of competence to assure that "fracture critical" members are in compliance with this fracture control plan;

1.1.4 requires American Society of Nondestructive Testing (ASNT) Level-II and Level-III personnel on the staff of both the fabricator and the Engineer for the inspection of "fracture critical" members; also that nondestructive testing be done both in quality control and in quality assurance;

1.1.5 requires that the designer have overall responsibility for implementation of this fracture-control plan, both in fabrication and in erection;

1.1.6 requires that the designer review the shop drawings, the weld-procedure-qualification testing, the weld-procedure specifications and the qualifications of the shop welding inspectors;

1.1.7 requires that the designer specify the methods to be used in nondestructive inspection and the specific joints to be inspected;

1.1.8 assigns responsibility for Quality Assurance to the designer, and requires that Quality Assurance verify the Quality Control as performed by the fabricator/erector both in the inspection of production-welding operations and in the nondestructive examination of FCMs.

1.1.9 specifies requirements which supersede the AWS/AASHTO Structural Welding Code for fabrication of "fracture critical" members;

1.1.10 requires more stringent weld-procedure qualification testing;

1.1.11 makes provision for testing production-welding procedures by use of extended run-off plates;

1.1.12 permits the substitution of production-weld-procedure testing for weld-procedure-qualification testing under 5.2 at the discretion of the Engineer;

1.1.13 requires more stringent controls in repair welding;

1.1.14 specifies more stringent control over welding consumables;

1.1.15 prohibits the use of "active" submerged-arc-welding fluxes in groove welds and fillet welds with more than three (3) passes;

1.1.16 prohibits the use of incomplete-penetration groove welds and fillet welds in tension components where the joint is transverse to the applied stress;

1.1.17 specifies fracture toughness values for weld metal and base metal based on the concept of through-thickness yielding, where the specified toughness values are a function of plate (and weld) thickness and yield strength;

1.1.18 requires that fracture testing be done no higher than the lowest anticipated service temperature (the LAST), where the LAST is based on a first percentile minimum temperature for the geographical location of the structure;

1.1.19 requires a nil-ductility transition (NDT) temperature 30°F below the lowest anticipated service temperature (LAST) with provision for "no-break" performance based on three (3) tests 20° below the LAST.

1.1.20 permits local stress relief of groove-weld butt-, T- and corner-joints when Charpy V-notch impact tests of weld metal fail to meet the specified toughness at the LAST.

1.2 Definitions.

1.2.1 Fracture critical members (FCMs) are those tension components whose failure would be expected to result in collapse of the structure.

1.2.2 Tension components of a structure consist of pure tension members and those portions of a flexural member that are subject to tension stress. The connecting welds in any attachment joined to a tension component of a FCM shall be considered part of the tension component and, therefore, shall be considered fracture critical.

1.3 Design and Review Responsibilities. The designer has full responsibility for suitability of the design of the structure for its intended purpose, including the selection of materials, weld details, and methods and locations for nondestructive inspection.

1.3.1 The responsibility for determining which, if any structural components fall in the FCM category shall rest with the designer.

The designer shall evaluate his design to determine the location of FCMs. The location of all members or components deemed "fracture critical" by the designer shall be clearly delineated on the contract plans. The designer shall review the shop drawings involving FCMs to assure that they show the location and extent of FCMs. A note on the first page of the contract plans shall state whether there are or are not FCMs.

1.3.2 The designer shall have a welding engineer review the contract plans and shop drawings for weld-joint design, the weld-procedure qualification and the weld-procedure specifications to assure conformance with the AWS/AASHTO Structural Welding Code, as amended herein. The welding engineer shall verify the qualifications of the Contractor's welding inspectors, and supervise the Quality Assurance welding inspection.

1.3.3 The designer shall verify the proper and sufficient implementation of this control plan for fracture-critical members. In addition to specifying which, if any, members are fracture critical, the designer shall verify compliance with this fracture-control plan at all stages of fabrication and erection.

1.3.4 All groove welds in tension-components and all attachment groove-welds contiguous to tension components shall be nondestructively inspected as specified in Section 6, as amended, and the welds shall be qualified by testing in accordance with Section 5, as amended.

The designer shall designate on the contract plans those welds which are to be ultrasonically tested (UT), radiographically tested (RT), magnetic-particle (MP) tested, eddy-current (EC) tested, and/or dye-penetrant (DP) tested. The specific welds to be nondestructively tested shall be designated with one or a combination of the following symbols: DP, EC, MP, RT and UT. All welds shall be visually inspected.

1.4 Fabricator Qualification Certification.

1.4.1 Structural steel fabricators shall be certified under the AISC Quality Certification Program, Category III, Major Steel Bridges, or other suitable program as determined by the Engineer before they are eligible to fabricate fracture-critical members.

1.5 Base Metal.

1.5.1 Steel types. The base metals to be used in FCMs are the carbon and low-alloy steels commonly used in the fabrication of steel structures including but not necessarily limited to the following ASTM types:

A 36

A 441

A 572 grades 42, 45, and 50

A 588

A 514

A 517

Whatever the steel used, it must be qualified by test using the procedures specified in Section 5 of the AWS/AASHTO Welding Code, as amended.

1.5.2 Plate edges. All plate to be used in FCMs shall be rolled on a "sheared mill" and furnished with oxygen-cut edges.

1.5.3 Plate thickness shall be limited to three (3) inches for yield strengths up to 90 ksi. With yield strengths greater than 90 ksi, the thickness shall be limited to two (2) inches.

1.5.4 Plate toughness. All plate used in FCMs shall be furnished to the Charpy V-notch (CVN) impact values specified in Table 1.5.4.

When retesting fails to produce 80 percent shear fracture as an indicator of upper-shelf performance (see footnote (a) of Table 1.5.4), the steel used in FCMs shall have a nil-ductility transition temperature (NDTT) at least 30°F below the LAST.

The NDTT shall be determined in accordance with ASTM E208 with the following modification; in plate 1 1/2-inches thick and thicker, the drop-weight test specimens shall be positioned so as to test the mid-thickness of the plate, i.e., the crack-starter weld bead shall be deposited in the plane of the plate midthickness.

The NDT test requirement will be satisfied by "no break" performance in triplicate specimens tested at a temperature corresponding to the LAST minus 20°F. The "no break" NDT performance criterion is described in ASTM E208-69 paragraph 15.1.

1.5.4.1 Lowest anticipated service temperature (the LAST). The LAST shall be based on the isoline in Figure 1.5.4.1 nearest the geographical location of the structure.

1.5.4.2 Impact-machine proof testing. In accord with ASTM E23, Charpy machines used in testing plate (and welds) of FCMs shall be proof tested with standarized specimens every six (6) months. Documentation based on the AMMRC report of evaluation shall be submitted to the Engineer prior to testing.

TABLE 1.5.4

CHARPY-IMPACT REQUIREMENT[a]
for
FRACTURE CRITICAL MEMBERS

YIELD[b] STRENGTH (ksi)	MINIMUM CVN-IMPACT (ft-lb)[c] AT THE LAST[d] FOR SPECIFIED THICKNESS RANGES (in.)		
	up to 2	over 2 to 2 1/2	over 2 1/2 to 3
from 36 to 60	25	30	35
over 60 to 70	30	35	40
over 70 to 80	35	40	45
over 80 to 90	40	45	50
over 90 to 100	45	(e)	(e)
over 100 to 110	50	(e)	(e)
over 110 to 120	55	(e)	(e)

NOTES: (a) The CVN-impact testing shall be "P" (plate) frequency testing; when more than one flange or web is stripped from a larger plate, only the larger plate need be tested. The Charpy test pieces shall be coded with respect to heat/plate number and that code shall be recorded on the mill-test report of the steel supplier with the test result. The fracture appearance at the LAST shall be no less than 80 percent shear (see ASTM A370-75, Section 23.2.2.1). If the fracture appearance in any one specimen is less than 80 percent shear (fibrous), a retest shall be made and the fracture appearance of each of the three retest specimens shall equal or exceed the 80 percent shear requirement. If the retest specimens fail to meet the fracture-appearance, ASTM E208 testing is required.

(b) The yield strength is the value given in the certified MILL TEST REPORT.

(c) Average of three (3) tests. If the energy value for more than one of the three test specimens is below the minimum average requirement, or if the energy value for one of the three specimens is less than 75 percent of the specified minimum average requirement, a retest shall be made and the energy value obtained from each of the three retest specimens shall equal or exceed the specified minimum average requirement.

(d) The lowest anticipated service temperature (the LAST) shall be based on the isoline in Figure 1.5.4.1 nearest the geographical location of the structure.

(e) Plate in excess of 2-inch thick shall not be used in FCMs when the yield strength exceeds 90 ksi.

FIGURE 1.5.4.1 - ISOLINES FOR FIRST-PERCENTILE MINIMUM TEMPERATURES, the basis for determining the lowest anticipated service temperature (LAST) for fracture critical members (FCMs).

FIGURE 1.5.4.1 - ISOLINES FOR FIRST-PERCENTILE MINIMUM TEMPERATURES, the basis for determining the lowest anticipated service temperature (LAST) for fracture critical members (FCMs).

1.5.5 Blast cleaning and weld conditioning. All plate used in FCMs shall be blast cleaned prior to assembly and welding. Blast cleaning shall meet the requirements of SSPC-SP6, Commercial Blast Cleaning.

Visual inspection for edge defects or laminations shall be performed prior to blast cleaning.

Plate edges which will later become part of a weldment involving complete-penetration butt welds shall be ultrasonic (UT) inspected prior to flame beveling or blasting, as required in 1.5.7.2.

1.5.5.1 Plate used in FCMs shall not be "conditioned" by welding in the mill; any welding done on plate in the steel mill shall be cause for rejection of the plate. Any weld conditioning of plate surfaces or plate edges shall be done in the fabricator's shop under the supervision of the fabricator's Quality Control organization and shall be done only with the written approval of the Engineer.

1.5.6 Straightening Material Prior to Fabrication. All deformed structural material shall be straightened prior to being laid out and worked in the shop. Sharp kinks and bends shall only be straightened with the written approval of the Engineer. Steel for use in FCMs shall not be cold bent without the written approval of the Engineer. Heat straightening shall be done in accordance with the provisions for Heat Curving and Cambering of Rolled Beams and Welded Plate Girders.

Heat straightening shall not be done on steels with yield strengths in excess of 90 ksi. In heat straightening quenched-and-tempered steels, the maximum temperature used in the operation shall not exceed the tempering temperature. In no case shall the maximum temperature exceed 1250°F.

1.5.7 Soundness of Plates and Shapes.

1.5.7.1 Laminar defects at edges and ends. All plates and shapes shall be subject to visual and ultrasonic inspection of edges and ends for the presence of laminar discontinuities and inclusions prior to blast cleaning. The shop inspector shall also determine by visual inspection that the steel contains no detrimental defects and that it meets the requirements of ASTM A20-74b unless otherwise specified.

Rejection or repair of laminar discontinuities discovered in the edges of plate up to 4-inch maximum thickness during the plant inspection at the time of fabrication is described in AWS D1.1 Table 3.2.3. Laminar defects in the edges of shapes discovered by visual examination will be subject to repair or replacement as determined by the Engineer.

1.5.7.2 Inspection of plate edges at tension groove welds. Ultrasonic testing (UT) requires, as a preliminary to angle-beam testing, inspection of the plate adjacent to all tension groove

welds using a straight-beam search unit as specified in 3.2.3 and Section 6. This UT inspection shall be performed by the fabricator and witnessed by the Engineer.

1.5.7.3 The repair of any discontinuity over 1-inch long with depth greater than 1-inch (see AWS Table 3.2.3) is subject to the written approval of the Engineer.

All manual welding shall be performed by qualified welders using low-hydrogen electrodes. Submerged arc welding and flux-cored arc welding may also be used with a qualified welding procedure and written approval of the Engineer.

Cavities resulting from the removal of discontinuities shall be prepared prior to welding with a minimum radius of 1/4-inch and a minimum included angle of 40 degrees. When the plate thickness is not sufficient for such preparation, repair welding will not be permitted.

1.5.8 Plate orientation. Unless otherwise specified on the contract plans, steel plate for FCMs shall be cut and fabricated so that the principal direction of rolling is parallel to the direction of the primary tensile stress. In plate subjected to biaxial tensile stresses (as in the web steel at the "knees" of a tied arch where the arch rib and tie girder are joined), the steel shall be specified as cross rolled, with a CVN-impact requirement for the specimen-transverse orientation of no less than 25 ft-lb at the LAST. The CVN-impact requirement for the speciment-longitudinal orientation shall be in accordance with 1.5.4.

2. DESIGN OF WELDED BRIDGES

The following changes in the AWS/AASHTO Structural Welding Code are mandatory for Fracture Critical Members (FCMs); paragraph numbers correspond to those of AWS D1.1-75, as revised.

2.1 Drawings.

The term "drawings" refers to plans, design and detail drawings contained in the contract plans, shop working drawings, and erection plans. No welds shall be made in or on FCMs that are not shown on the drawings.

2.1.1 (The present paragraph 2.1.1 shall be deleted and replaced with the following:)

2.1.1 Full and complete information regarding location, size and extent of all welds shall be clearly shown on the contract plans. The type of weld (manual, submerged arc, flux-cored arc, etc.) shall not be designated on the design drawings. The contract plans shall clearly designate complete-penetration groove welds and partial-penetration groove welds, with dimensions on the latter to show size.

2.1.1.1 Shop drawings shall show the location, type, size and extent of all welds. The joint-design details shall conform to AWS/AASHTO Section 2 paragraphs 2.9.1, 2.10.11, 2.11.1, 2.12.1, 2.13.1 and 2.14.1, as amended. No welds shall be made in or on FCMs that are not shown on the shop drawings.

2.1.1.2 Erection plans shall show the location, type, size and extent of all field welds. The erection plans shall be approved by the Engineer in writing prior to any field welding. The erection plans shall clearly distinguish between shop and field welds. The term "field weld" refers to any weld, including temporary attachments for purposes of erection, done off the premises of the fabricator's shop.

2.1.1.3 Railroads shall be prohibited from welding temporary attachments for shipping purposes.

2.3 Effective Weld Areas, Lengths and Throats.

2.3.5 In fracture critical members (FCMs), plug and slot welds, intermittant fillet welds, partial-penetration groove welds, and splice details of AWS D1.1 Figures 2.4.2 and 2.4.3 shall not be used.

2.3.6 In FCMs, all groove-weld butt- and corner-joints shall be ground flush.

2.5 Partial Joint Penetration Groove Welds.

(The present paragraph 2.5 shall be deleted and replaced as follows:)

Partial penetration groove welds subject to tension normal to their longitudinal axis shall not be used in FCMs.

Holes or slots in members or components to permit passage of another member or component through the member or component shall not be welded to seal or otherwise close the hole or slot.

2.6 Joint Qualification.

2.6.1 (The present paragraph 2.6.1 shall be deleted and replaced as follows:)

2.6.1 Joint design configurations that are in conformance with the details specified in AWS D1.1 Figures 2.9.1 through 2.9.14, inclusive are prequalified for FCMs except as restricted under 2.5.

2.7 Details of Fillet Welds.

2.7.1.1 (The present paragraph 2.7.1.1 shall be deleted and replaced as follows:)

2.7.1.1 The minimum fillet-weld size, except for fillet welds used to reinforce groove welds, shall be as shown in Article 1.7.21(B) of the AASHTO Bridge Specifications, page 161.

2.7.1.2 (The present paragraph 2.7.1.2 shall be deleted and replaced as follows:)

2.7.1.2 The maximum fillet-weld size shall conform to Article 1.7.21(C) of the AASHTO Bridge Specifications, page 161.

2.7.1.6 Fillet welds shall be used to develop shear only and shall not be used to transfer tension or compression normal to the axis of the weld.

2.7.1.7 Sealing welds shall not be used in FCMs under any condition which will provide rigidity or restraint to the connected members.

2.8 Plug and Slot Welds.

(The present paragraphs 2.8.1 through 2.8.8, inclusive, shall be deleted and replaced as follows:)

2.8 Allowable Stresses.

2.8.1 Basic unit stresses for base metals and for effective areas of weld metal for application to bridges shall be as shown in Section 7-Structural Steel Design, AASHTO Standard Specifications for Highway Bridges, Latest Edition, including current interim specifications.

2.8.2 Fatigue stress provisions. Allowable fatigue stresses for base metals and for effective areas of weld metal for application to bridges shall be as shown in Section 7-Structural Steel Design, AASHTO Standard Specifications for Highway Bridges, Latest Edition, including current interim specifications.

2.8.2.1 Fatigue categories D and E shall not be used in FCMs.

2.8.3 Combined unit stresses. In the case of axial stress combined with bending, the allowable unit stress of each kind shall be governed by the requirements of 2.8.1 and 2.8.2 and the maximum combined unit stresses calculated therefrom shall be limited in accordance with the requirements of the applicable general specifications.

2.15 Structural Details.

2.15.1 General. In general, details shall minimize constraint against ductile behavior, avoid undue concentration of welding, and afford ample access for depositing the weld metal.

2.15.2 Noncontinuous beams. The connections at the ends of noncontinuous beams shall be designed with flexibility so as to avoid excessive secondary stresses due to bending.

2.15.3 Participation of floor system. Details of the floor system should be so designed as to avoid, in so far as possible, unintended participation in the chord or flange stresses.

2.15.4 Lap joints. Lap joints shall not be used in FCMs.

2.15.5 Corner and T joints. Corner and T joints that are to be subjected to bending about an axis parallel to the joint shall have their welds arranged to avoid concentration of tensile stress at the root of any weld.

2.15.6 Prohibited types of joints and welds. The joints and welds listed in the following paragraphs are prohibited:

2.15.6.1 Butt joints not fully welded throughout their cross section.

2.15.6.2 Groove welds made from one side only

(1) without backing,

(2) with backing other than steel

These prohibitions for groove welds made from one side only shall not apply to (1) secondary or non-stress carrying members, for shoes, etc., where such welds are not contiguous to an FCM, and (2) corner- and T-joints parallel to the applied stress between components of built-up members designed primarily for axial stress.

2.15.6.3 Intermittent groove welds.

2.15.6.4 Intermittent fillet welds.

2.15.6.5 Bevel-grooves and J-grooves in butt joints for other than horizontal positions (see AWS D1.1 Figures 2.9.1 and 2.13.1).

2.15.6.6 Partial-penetration fillet welds and groove-weld butt-, T- and corner-joints perpendicular to the applied stress.

2.15.6.7 Joints perpendicular to the applied stress with backing left in place or backing fillet welded outside the groove weld.

2.15.6.8 Any temporary weld made in the steel mill, in fabrication, in transportation and/or in erection not shown on the drawings.

2.15.6.9 Field welding of FCMs is prohibited; in erection all connections shall be made by bolting.

2.15.7 Combinations of welds. If groove and fillet welds are combined in a single joint, the allowable capacity of each shall be separately computed, with reference to the axis of the group, in order to determine the allowable capacity of the combination.

2.15.8 Welds in combination with rivets and/or bolts.

2.15.8.1 In new work, rivets or bolts in combination with welds in a single connection detail shall not be used where both weld and fastener will share in the transfer of stress.

2.15.8.2 Bolts used in assembly may be left in place if their removal is not specified. If bolts are removed or mislocated, correction shall not be made by welding except under 3.7.4 and with written approval by the Engineer.

2.15.8.3 In the design of attachments to FCMs, to the maximum extent possible, connection of the attachment (stringers, gussets, etc.) shall be a bolted connection (see Section 10-Steel Structures, AASHTO Standard Specifications for Highway Bridges, 12th Edition, 1977, Division II, Construction, paragraphs 2.10.7 through 2.10.20).

2.15.9 Eccentricity of connection.

2.15.9.1 Eccentricity between intersecting parts and members shall be avoided in so far as practicable.

2.15.9.2 In designing welded joints, adequate provision shall be made for bending stresses due to eccentricity, if any, in the disposition and section of base metal parts and in the location and types of welded joints.

2.15.9.3 For members having symmetrical cross sections, the connection welds shall be arranged symmetrically about the axis of the member, or proper allowance shall be made for unsymmetrical distribution of stresses.

2.15.9.4 For axially-stressed angle members, the center of gravity of the connecting welds shall lie between the line of the center of gravity of the angle's cross section and the center line of the connected leg. If the center of gravity of the connecting weld lies

outside of this zone, the total stresses, including those due to the eccentricity from the center of gravity of the angle, shall not exceed those permitted by this code.

2.15.10 Connections or splices.

2.15.10.1 Connections or splices of tension or compression members made by groove welds shall have complete joint penetration welds.

2.15.10.2 If members subject to compression only are spliced with full-milled bearing, the splice material and its welding shall be arranged, unless otherwise stipulated by the applicable general specifications, to hold all parts in alignment and shall be proportioned to carry 50 percent of the computed stress in the member. Where such members are in full-milled bearing on base plates, there shall be sufficient welding to hold all parts securely in place.

2.15.10.3 When a member is made of two or more pieces, the pieces shall be connected along their longitudinal joints by continuous welds to make the pieces act in unison.

2.15.11 Transition of Thickness or width at butt joints. When butt joints are used to join material of different thickness or width, there shall be a smooth transition slope between the offset surfaces or edges. This slope shall not exceed that shown in AWS D1.1 Figure 9.20.2.

2.15.11.1 The transition of thickness may be accomplished by sloping weld faces, chamfering the thicker part, or a combination of the two methods.

2.15.11.2 The transition of width shall be accomplished by sloping the edges of the wider part.

2.15.12 Girders and beams.

2.15.12.1 Connections or splices in beams or girders when made with groove welds shall have complete joint penetration welds.

2.15.12.2 Splices between sections of rolled beams or built-up girders shall preferably be made in a single transverse plane. Shop splices of webs and flanges in built-up girders, made before the webs and flanges are joined to each other, may be located in a single transverse plane or multiple transverse planes, but the fatigue stress provisions of the general specification shall apply.

2.15.12.3 Stiffeners. If stiffeners are used on only one side of the web, they shall be welded to the compression flange.

Stiffener-to-web connections perpendicular to the applied stress in a tension member shall be a complete-penetration groove-weld T-joint, except as provided under 4.1.1.2.7.

Stiffener-to-web connections perpendicular to the applied stress in flexural members, in locations of tension stress the connections shall be a complete-penetration groove-weld T-joint for one-third

(1/3) the depth of the girder but not less than two (2) feet. The remaining 2/3 of the stiffener-to-web connection may be an incomplete penetration fillet weld. For exception see 4.1.1.2.7.

The groove-weld T-joint welding procedure for welds perpendicular to the applied stress shall be qualified by testing, per 5.2, as amended.

Diaphrams and hangers involving flange and/or web connections perpendicular to the applied stress shall be a complete-penetration groove-weld T joint. For exception see 4.1.1.2.7.

2.15.12.4 Girders (built-up I sections) shall preferably be made with one plate in each flange, i.e., without cover plates. The unsupported projection of a flange shall be no more than permitted by the applicable general specification. The thickness and width of a flange may be varied by butt welding parts of different thickness or width with transitions conforming to the requirements of 2.15.11.

2.15.12.5 Cover plates. Cover plates shall be limited to one on any flange. The maximum thickness of cover plates on a flange shall be no greater than 1-1/2 times the thickness of the flange to which the cover plate is attached. The thickness and width of a cover plate may be varied by butt welding parts of different thickness or width with transitions conforming to the requirement of 2.15.11. Such plates shall be assembled and welds ground flush before

attaching to the flange. The width of a cover plate, with recognition of dimensional tolerances allowed by ASTM Specification A6, shall allow suitable space for a fillet weld along each edge of the joint between the flange and the plate cover.

In FCMs, when partial-length cover plates are used, the ends of cover plates shall be in sections where the stress is compression. The ends of the cover plate shall be cut square, and a continuous fillet weld shall be deposited across the end and along both edges of the cover plate or flange to connect the cover plate to the flange. The fillet welds shall not terminate at the corners of the cover plate, 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. Boxing shall be indicated on design and detail drawings.

Fillet welds connecting a cover plate to the flange in the region between terminal developments shall be continuous welds of sufficient size to transmit the incremental longitudinal shear between the cover plate and the flange. Fillet welds in each terminal development shall be of sufficient size to develop the cover plate's portion of the stress in the beam or girder at the inner end of the terminal development length and in no case shall the welds be smaller than the minimum size permitted by 2.7.1.1.

3. WORKMANSHIP

3.1 General. For FCMs, there are requirements which supersede those presently specified in the AWS/AASHTO Structural Welding Code Section 3.

3.1.2 (Add a sentence to the present paragraph:) Free-hand oxygen cutting shall be done only where approved by the Engineer in writing.

3.1.3 (The present paragraph 3.1.3 shall be deleted and replaced with the following:) Welding shall not be done when the ambient temperature is lower than 50°F or when the surfaces are wet or when the welding operation is exposed to excessive air movement.

3.1.5 Temporary welds, welds to fitting aids, and tack welds not incorporated in a joint shown on the drawings (see 2.1) shall not be used during assembly, for shipment or in erection of FCMs unless detailed on the appropriate drawings and approved by the Engineer in writing.

3.1.6 So-called cosmetic welding shall be treated as a weld repair as specified in 3.7, as amended, with the following exception:

3.1.6.1 Surface discontinuities that can be removed by superficial grinding may be corrected without adherance to the provisions of 3.7.

3.2 Preparation of Base Metal.

3.2.1.1 In preparation for welding FCMs, no mill scale shall be permitted to remain in the boundary of a groove weld.

3.2.3 Visual inspection and repair of plate cut edges.

3.2.3.1 In FCMs, all plates and shapes shall be subject to visual inspection of edges and ends for the presence of laminar discontinuities and inclusions as specified in 1.5.7 prior to blast cleaning.

3.2.3.2 In FCMs, nondestructive testing of tension groove welds shall include both ultrasonic (UT) and radiographic (RT) testing. As a preliminary to angle-beam UT testing, the plate edges adjacent to all tension groove welds shall be inspected prior to assembly of the joint using a straight-beam UT search unit as specified in AWS D1.1 Section 6, as amended (see 6.19.4.2).

3.2.3.3 In FCMs, the following sequence will be used to determine if, in the plate edges at the boundary of tension groove welds, laminar defects are present that will require rejection and replacement, or repair under provision of this specification.

3.2.3.3.1 If during vusual or UT inspection, laminar defects are discovered at any location in the plate edges, the plate edges adjacent to the tension groove weld shall be subjected to magnetic-particle (MP) inspection after the edges have been beveled preparatory to welding.

3.2.3.3.2 If during the MP inspection laminar defects are discovered, UT will be used to search the end six (6) inches of the plate adjacent to the tension groove weld.

3.2.3.3.3 When UT is required, the test procedure described in AWS Section 6 as amended shall be performed by the Contractor and witnessed by the Engineer (see 6.19.4.2).

3.2.3.3.4 In addition to the UT requirements, if it is found by MP inspection that the sum of the laminar-defect lengths in the plate edge adjacent to the tension groove weld exceeds 15 percent of the total length of the joint, the steel shall be rejected for use as a boundary for a tension groove weld.

3.2.3.4 In FCMs, when the above inspection procedures reveal rejectable defects at plate edges which are to form the boundary of a tension groove weld, one of the following methods of repair may be approved in lieu of replacement of the entire plate:

3.2.3.4.1 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 certified mill test reports show that the plate is of the same type and grade as the plate being replaced and meets the plate toughness requirement. The minimum length of added plate shall be five (5) feet unless otherwise approved in writing by the Engineer. The boundary of the additional tension groove weld shall be subjected to MP inspection and shall be subject to the provisions of 3.2.3.3.2, 3.2.3.3.3 and 3.2.3.3.4. The additional butt weld resulting from the added plate shall be subject to both ultrasonic and radiographic inspection

in addition to the originally detailed weld inspection required by the Specifications. The direction of rolling of the replacement plate shall be in the direction of stress in the member. The repair procedure shall be submitted to the Engineer for written approval and shall be shown as a revision to the approved shop drawings prior to the final acceptance of the repair.

3.2.3.4.2 When the sum of all laminar defects at the boundary of the tension groove weld does not exceed fifteen (15) percent 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 (6) 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 re-evaluated as described in paragraph 1.5.7.2.

The cavity in the edge or end of the plate and any excavation from a plate surface shall have a minimum radius of 1/4 inch at the root and the sides shall slope back to a minimum angle of 20° (40° included angle). 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 (6) inches shall be retested by the Ultrasonic Test procedure described in this specification to insure the complete removal of the laminar defects. The area repaired by welding shall also be inspected for weld defects by RT and UT testing.

The repair procedure shall be submitted to the Engineer for approval prior to the initiation of repairs.

3.2.4 (The present paragraph 3.2.4 shall be deleted and replaced with the following:) Reentrant corners, except for the corners of weld-access cope holes adjacent to a flange, shall be filleted to a radius of no less than one (1) inch. The fillet and its adjacent cuts shall meet without offset or cutting past the point of tangency.

3.2.5.1 All air carbon-arc gouged surfaces shall be ground to bright metal after gouging to remove any carbon pick-up.

3.2.5.2 All plates in FCMs shall have their longitudinal edges prepared by flame cutting. Gusset plates, stiffeners, diaphrams and other secondary attachments may be furnished with sheared or universal-mill edges.

3.7 Weld Repairs. The AWS Structural Welding Code, paragraph 3.2, 3.7, 4.4 and 5.2 are supplemented by a mandatory requirement that all repairs to base and weld metal be documented giving the details of the type and

extent of defects. Weld-repair procedures shall be approved by the Engineer prior to initiating repairs. Repair welding is defined as any welding, including removal of weld or base metal in preparation for welding necessary to correct defects in materials or workmanship.

3.7.1 Repair welding may be performed using any of the welding procedures qualified for use in the fabrication of FCMs. All repair welding shall be subject to nondestructive tests as provided herein.

3.7.2 Repair welding which consists solely of the deposition of additional weld beads to compensate for insufficient weld throat or to remove undercut shall not require prior approval of the Engineer <u>providing the deficiency is detected and corrected before the preheat/interpass temperature falls below the specified minimum (see 4.2.2.2)</u>.

3.7.3 For noncritical repairs the Contractor may prepare written repair procedures and submit them to the Engineer for preapproval. Preapproved prequalified procedures may be employed after the Engineer has verified that any given defect to be repaired is as described in the approved procedure. <u>Noncritical repairs which may be prequalified include the following</u>:

A. Gouges in cut edges that are less than 7/16-inches deep.

B. Lamellar discontinuities less than one-inch deep, or with a depth of less than one-half the thickness of the plate cut edge, whichever is less, provided the lamellar defect is not within 6 inches of a tension groove weld. There shall be no visible lamellar discontinuities in the boundaries of tension groove welds. Repair of such discontinuities by the "blocking-off" method will not be authorized.

C. The repair of base metal surfaces when ASTM A20 provides for repair by welding. Repair shall be performed as described in the approved procedure and is subject to 1.5.5.1.

D. First-time excavation and repair from one surface of groove welds and of fillet welds which contain porosity, slag or incomplete fusion provided the excavation does not exceed the following limits:

Weld Length "L"	Total Length of Excavation
Up to 1'-6"	"L" or 10" whichever is less
Over 1'-6" to 3'	1'-0"
Over 3' to 6'	1'-6"
Over 6' to 12'	2'-0"
Over 12' to 24'	3'-0"
Over 24'	3'-0" or 10 percent, whichever is greater

and the depth of the excavation does not exceed 65 percent of the effective throat of the weld as detailed on the Plans.

3.7.4 Critical repairs shall be individually approved by the Engineer before repair welding is begun. Critical repairs include the following:

A. Gouges in cut edges 7/16-inches deep or deeper.

B. Repair of lamellar defects not provided for in 3.7.3. Lamellar defects of the type designated W and X in AWS D1.1 Figure 3.2.3.3 shall not be "blocked-off" by welding and shall not be permitted in the boundaries of groove welds subject to applied tensile stress.

C. Repair of surface or internal defects in rolled, forged or cast products except as provided in 3.7.3.

D. Repair of weld defects except as provided in 3.7.3.

E. Repair of any cracks including base metal separations such as lamellar tears. One exception will be allowed; viz., first-time excavation and repair of the root pass for "hot" or "restraint" cracking in any given joint.

F. Dimensional corrections requiring weld removal, rewelding or the use of heat and/or force.

G. Any weld correction to compensate for a fabrication error such as improper cutting, punching, drilling, machining, fitting, assembly, etc.

3.7.5 Repair procedures for noncritical and critical repairs shall include dimensioned isometric projections or full-scale plan view, elevation

and section drawings to describe the deficiency as it appears prior to repair and the proposed method of repair, and to accurately locate the repair within the bridge member.

3.7.6 The repair drawings shall be revised as necessary to show any difference between the initial type, size, location and orientation of defects and the final quantification of the flaw as determined during the repair. Repair drawings shall contain two signature lines; signature on the first line shall indicate the Inspector (6.1.4) has examined the defect(s) and agrees that the repair drawings accurately describe the flaw(s). When repairs are completed, the Inspector's signature on the second line shall indicate acceptance of the completed repair and the specified nondestructive tests.

3.7.6.1 The isometric projection and/or full-scale drawing as described in 3.7.6 shall become part of the QC/QA permanent records on each repair in any FCM.

3.7.7 Repair procedures shall include at least the following steps in the order to be performed:

A. Surfaces shall be cleaned and ground as necessary to aid in visual and nondestructive testing, and to enable the Contractor and Inspector to identify and quantify the defect(s).

B. The defect shall be shown on the repair drawing as it appears from visual inspection and nondestructive examination.

C. Preheat for arc-air gouging shall be listed. The method and extent of excavation shall be completely described giving the sequence of progressive excavations.

D. All air carbon-arc gouged and oxygen-cut surfaces that form a boundary for a repair weld shall be ground to form a smooth, bright surface. Oxygen gouging is not permitted in FCMs.

E. Magnetic-particle or dye-penetrant inspection shall be used to determine if the defect has been completely removed.

F. All required run-off tabs and back-up bars shall be shown in the procedural details.

G. Preheat and interpass temperature shall be given. Quenched-and-tempered (Q&T) steels shall be heated as shown in Table 4.2 except that the MAXIMUM temperatures shall be used whenever this temperature plus the heat input from welding does not exceed the steel manufacturer's recommendations. Steels in the as-rolled, control-rolled or normalized condition with thicknesses up to 1-1/2 inches shall be heated to 350°F minimum. Thicknesses over 1-1/2 inches shall be heated to 450°F minimum. Preheat/interpass and postheat temperatures shall be maintained without interruption until the repair is completed. Postheating shall be as specified in 4.2.3.

H. Joint welding details (edge preparation) prequalified by AWS D1.1 and approved for FCM fabrication need not be requalified if the geometry and sequence of excavations and rewelding provides good access to all portions of the weld joint or excavation in the opinion of the Engineer.

I. Peening, if required, shall be completely described in the written weld-repair procedure. In addition to the provisions of AWS D1.1 paragraph 3.8, peening shall be performed at temperatures between the minimum preheat/interpass temperature and 600°F maximum. Peening equipment shall not contaminate the surface of the weld.

The striking end of the peening tool shall be finished in the form of a hemisphere with a minimum radius of 1/4 inch. Peening tools shall be directed against the convex surfaces of weld layers or bead; they shall not strike the base metal or the fusion boundary between the weld and base metal.

J. Postheat shall be employed and shall continue without interruption from the completion of repair welding to the end of the minimum specified postheat period. Postheat shall be at 450°F for a minimum of one (1) hour for each inch of thickness in the cross section being repair welded. The maintenance of preheat/interpass temperature during repair and postheat shall be continuous operations.

K. Repair-weld surfaces shall be ground flush with the plate surface or blended to the same contour and throat dimensions as the adjoining weld.

L. If stress-relief heat treatment is required, it shall be completely described in the written weld-repair procedure. Tests shall be performed to determine the effect of the stress relief on the weld metal properties before the procedure is approved. Final acceptance nondestructive inspection shall be performed after stress relief.

M. Repair welds shall be nondestructively examined. The testing shall be done according to AWS D1.1 Section 6, as amended. Initial testing may be performed as soon as the weldment has cooled to ambient temperature. Final acceptance of repair welds involving base metal and/or welding consumables with yield strengths up to 90 ksi shall be based on nondestructive examination conducted no sooner than 72 hours after the repair is completed. For base metal and/or welding consumables with yield strength over 90 ksi, the final-acceptance nondestructive examination shall be conducted no sooner than 96 hours after the repair is completed.

3.7.8 The repair-welding-procedure specification shall completely describe the procedure, including the weld technique (stringer beads, width of weave, "buttering", back-stepping, sequence of passes, etc.).

Noncritical repairs should be made using the qualified welding procedure of the joint being repaired or a joint elsewhere in the bridge member. If the volume removed in excavating the defect is too small for automatic welding, shielded metal-arc welding or a semi-automatic qualified welding procedure may be used.

For critical repairs, if the weld-repair procedure is not the same (subject to AWS D1.1 5.5 "limitation of variables") as the qualified welding procedure used in the joint being repaired, the weld-repair procedure shall be subjected to testing as specified in AWS 5.2, as amended.

3.7.9 All repair welding and nondestructive testing shall be performed as described in the approved repair procedure.

3.7.10 The location of repaired areas shall be shown on revised shop drawings. Repair procedures and dimensioned isometric sketches of repairs as specified in 3.7.6 shall be retained as part of the project records.

3.8 Peening.

(The present paragraph 3.8 shall be deleted and replaced with the following:)

3.8.1 In FCMs where it is required that groove welds be ground flush, peening may be done on the surface layer of the weld. No peening shall be done on the root or on the base metal at the edges of the weld.

The peening shall be done at temperatures between the minimum preheat/interpass temperature and 600°F maximum.

The striking end to the peening tool shall be finished in the form of a hemisphere with a minimum radius of 1/4 inch. Peening tools shall be directed against the CONVEX SURFACES of weld layers or bead; they shall not strike the base metal or the fusion boundary between the weld and base metal.

In peening intermediate layers, the peening shall not contaminate the surface of the weld with grease or any other foreign substance.

3.8.2 When peening is to be used in production welding, the peening shall be completely described in the welding-procedure specification.

3.9 Stress Relief Heat Treatment.

(The present paragraphs 3.9.1, 3.9.1.1 and 3.9.2 shall be deleted and replaced as follows:)

3.9.1 When local stress relief is performed (as in 3.7.7(L) and 4.1.1.2.3) the precedure shall be as specified in 4.1.1.2.4.

3.9.2 When stress relieving is done, the stress-relief treatment shall be part of the weld-procedure specification, and weld-procedure-qualification testing shall be done after stress relieving.

3.9.3 Groove welds that have been stress relieved may be given final nondestructive inspection as soon as the weld has cooled to ambient temperature.

4.1 Filler Metal Requirements.

4.1.1 The electrode, electrode-flux combination, or grade of weld metal for making complete-penetration butt welds shall be in accordance with AWS D1.1 Table 4.1.1 with the following exceptions for FCMs:

4.1.1.1 In submerged-arc welding, "active" fluxes shall not be used in groove welds or fillets with over three (3) weld passes.

4.1.1.2 The weld metal of groove welds deposited with the qualified welding procedure shall have Charpy V-notch impact values when tested at the lowest anticipated service temperature (the LAST) as specified in Table 4.1.1.2.

4.1.1.2.1 Groove-weld joints may be qualified by the ASTM E399 Standard Method of Test as an alternative to the Charpy V-notch impact test requirement of Table 4.1.1.2.

The weld metal deposited using the qualified welding procedure shall meet the requirements of Table 4.1.1.2.1. The E399 testing shall be done with 1-inch specimens.

4.1.1.2.2 When static E399 testing is used in lieu of dynamic (Charpy impact) testing, groove-weld butt-, T- and corner-joints perpendicular to the applied stress additionally shall meet the following Charpy impact test requirement at the LAST:

DEPOSITED WELD METAL

YIELD (KSI) STRENGTH	CHARPY FT-LB
up to 90	35
over 90	45

TABLE 4.1.1.2

WELD METAL
CHARPY-IMPACT REQUIREMENT[a]
for
FRACTURE CRITICAL MEMBERS

WELD METAL YIELD[b] STRENGTH (ksi)	MINIMUM CVN-IMPACT (ft-lb)[c][d] AT THE LAST[e] FOR SPECIFIED THICKNESS RANGES (in.)		
	up to 2	over 2 to 1 1/2	over 2 1/2 to 3
from 36 to 60	25	30	35
over 60 to 70	30	35	40
over 70 to 80	35	40	45
over 80 to 90	40	45	50
over 90 to 100	45	50	(f)
over 100 to 110	50	55	(f)
over 110 to 120	55	60	(f)

NOTES: (a) Charpy specimens taken from weld-procedure-qualification test plates (see 5.1.1.1) and from run-off production-weld sampling (see 4.1.1.4). In weld-procedure-qualification tests of groove-weld butt joints and T- and corner-joints which are to be perpendicular to the applied stress, the fracture appearance at the LAST shall be no less than 80 percent shear (see ASTM A370-75, Section 23.2.2.1).

(b) The weld-metal yield strength is the value as measured in weld-procedure-qualification test plates or in production-weld run-off plates.

(c) A Charpy "test" shall be made with five (5) weld-metal Charpy specimens. When computing the average, the lowest value and the highest value obtained from the five specimens shall be disregarded. If the value for more than one of the three values averaged falls below the specified minimum value, or if one of the values averaged is less than 2/3 of the specified minimum value, a retest shall be made and the value obtained from all three specimens must equal or exceed the specified minimum average value.

(d) If the fracture appearance of one of the specimens used in computing the average energy value is less than 80 percent shear, a retest shall be made and the fracture appearance of each of the three retest specimens shall equal or exceed 80 percent shear.

(e) The lowest anticipated service temperature (the LAST) shall be based on the isoline in Figure 1.5.4.1 nearest the geographical location of the bridge.

(f) Plate in excess of 2-inch thick shall not be used in FCMs when the yield strength exceeds 90 ksi.

TABLE 4.1.1.2.1

PLANE-STRAIN FRACTURE TOUGHNESS OF WELD METAL

MINIMUM E399 KQ at the LAST

YIELD STRENGTH (ksi)	FOR SPECIFIED THICKNESS RANGES				
	up to 1	over 1 to 1 1/2	over 1 1/2 to 2	over 2 to 2 1/2	over 2 1/2 to 3
up to 50	50	60	70	80	85
over 50 to 60	60	75	85	95	105
over 60 to 70	70	85	100	110	120
over 70 to 80	80	100	115	130	140
over 80 to 90	90	110	130	145	155
over 90 to 110	100	125	140	160	(f)
over 100 to 110	110	135	155	175	(f)
over 110 to 120	120	145	170	190	(f)

NOTES:

(1) For purposes of this specification, K_Q shall be based on strength ratio as measured in one (1) inch compact specimens or one (1) inch bend specimens (see ASTM E399-74 paragraphs 1.3, 9.1.6 and 9.1.7).

(2) When the compact specimen is used, the K_Q value shall be calculated from the expression

$$K_{Ic} / FTY = 0.68\ R_{sc}$$

where R_{sc} is the specimen strength ratio (E399-74 paragraph 9.1.7) and FTY is the yield strength from the mill test report.

(3) When the bend specimen is used, the K_Q value shall be calculated from the expression

$$K_{Ic} / FTY = 0.63\ R_{sb}$$

where R_{sb} is the specimen strength ratio (E399-74 paragraph 9.1.6) and FTY is the yield strength from the mill test report.

(4) The lowest anticipated service temperature (the LAST) shall be based on the isoline in Figure 1.5.4.1 nearest the geographical location of the bridge.

4.1.1.2.3 Groove-weld joints not meeting the toughness requirements of 4.1.1.2, 4.1.1.2.1 and 4.1.1.2.2 may be locally stress relieved at 1150°F ±25°, or at a temperature 50° below the tempering temperature in quenched-and-tempered (Q&T) steels.

When the mill test report indicates a tempering temperature below 1150°F, the welds shall not be stress relieved.

4.1.1.2.4 Local stress-relief treatment shall be accomplished by electric-resistance heating or an equivalent method; torch heating shall not be used. The width of the heated zone on each side of the weld shall be at least three (3) times the base-metal thickness or six (6) inches whichever is the larger dimension. Plate on either side of the groove-weld joint shall be insulated during and after stress relief to assure slow uniform cooling. The soaking time shall be one (1) hour per inch of thickness; at a transition butt joint, a T joint or a corner joint, the soaking time shall be one (1) hour per inch of the thicker of the adjacent groove-welded plates. The heating and cooling rates shall not exceed 400°F per hour divided by the thickness of the plate being joined (or the thickness of the thicker plate). In no case shall the temperatures measured at a point 2 inches from the weld centerline on either side of the joint be different by more than 75°F.

4.1.1.2.5 When stress relieving is necessary under 4.1.1.2, 4.1.1.2.1 and 4.1.1.2.2, the stress-relief treatment shall be

made a part of the weld-procedure specifications subject to AWS D1.1 paragraph 5.5, as amended. Weld-procedure qualification testing as required in AWS D1.1., as amended, and nondestructive inspection as required in AWS D1.1 Section 6, as amended, shall be done after stress relieving.

4.1.1.2.6 Groove welds that have been stress relieved may be nondestructively inspected as soon as the weld has cooled to ambient temperature.

4.1.1.2.7 Where the welds are perpendicular to the applied stress, in lieu of complete-penetration groove-weld T- and corner-joints, partial-penetration fillet welds may be approved by the Engineer providing fillet welding-procedure-qualification testing meets the Charpy V-notch impact requirement of 5.10.3.4 and 5.12.1.7.

4.1.1.3 The yield strength and toughness of deposited weld metal shall be based on mechanical testing of welds made with the qualified welding procedures.

4.1.1.4 When required by the Engineer, a sample (test) joint of the same cross section as the joint in construction shall be provided for testing by means of an extended "run-off" plate.

4.1.1.4.1 The Engineer may require sampling of up to ten (10) percent of the groove-weld butt splices.

4.1.1.4.2 The run-off plate shall be of sufficient length to permit all-weld-metal tensile and Charpy specimens, as specified in AWS 5.2, amended.

4.1.1.4.3 The run-off plate shall be of the same type and grade as the member being fabricated and shall have the same edge preparation and joint design as the plate being spliced. The welding of the member being fabricated and the welding of the run-off plate shall be done without interruption as one continuous operation.

4.1.1.4.4 Any production weld, sampled by testing a run-off plate, that fails to meet the toughness requirements shall be stress relieved as specified in 4.1.1.2.3 and 4.1.1.2.4, and any untested production welds made to the same weld-procedure specification also shall be stress relieved.

Before stress relieving production welds, a test plate shall be prepared using the weld-procedure specification in question, stress relieved in accordance with 4.1.1.2.3 and 4.1.1.2.4 and tested for compliance with 4.1.1.2.

4.1.1.4.5 It shall be the Contractor's responsibility to replace or bolt splice any weld joints that do not meet the toughness requirements as specified for FCMs. All corrections require the written approval of the Engineer.

4.1.1.5 With well-documented evidence of a prequalified procedure, the Engineer may accept production-welding-procedure testing in lieu of weld-procedure-qualification testing.

4.1.1.5.1 When run-off plate production-welding-procedure testing is allowed by the Engineer in lieu of 5.2 testing, the frequency of testing and the type of testing shall be the same as specified for weld-procedure-qualification testing except that bend and transverse tensile testing will be waived.

4.1.1.5.2 In the event the production-weld testing fails to give the specified toughness values, the requirements of 4.1.1.4.4 shall be met.

4.1.2 (The present paragraph 4.1.2 shall be deleted and replaced with the following:) The electrode, electrode-flux combination, or grade of weld metal for complete-penetration welds in shear, partial-penetration groove welds in shear, and for fillet welds in shear may be of lower strength than that required to match the base metal, provided the weld meets the stress requirements specified by design.

4.1.2.1 For plate with a specified yield strength of 50 ksi or greater, welding processes, electrodes, electrode-flux combinations, and/or grades of weld metal that have a yield strength overmatching the specified yield strength of the base metal by more than 25 percent shall not be used in FCMs.

4.1.2.2 Welding procedures for groove-weld corner- and T-joints that are perpendicular to the applied stress in FCMs shall be qualified in accordance with AWS 5.2, as amended.

4.1.2.3 Each shipment of consumables shall be accompanied by the producer's certification as to heat/lot/batch in the shipment.

4.1.2.4 Each heat/lot of electrode and welding wire shall be pretested in accordance with ASME Section III Nuclear Specifications and certified as manufactured in compliance with paragraph NB-2400, Section III (1974), Class 1, components, of the ASME Boiler and Pressure Vessel Code, except for "lot" definition. The material shall be manufactured to the lot definition approved by ASME Code Case 1567 using one heat of core wire. Each electrode and wire container shall be identified by heat and lot number.

4.1.3.1 Each package shall be identified by heat/lot and certified as to the hydrogen content of each heat of wire.

4.1.3.1.1 Each heat of wire shall be certified as having less than 5 ppm hydrogen measured by vacuum fusion analysis.

4.1.3.1.2 The wire shall be analyzed "as-supplied" without abrading or otherwise cleaning the wire surface.

4.1.3.1.3 Check analyses ordered by the Engineer shall be based on a sample taken from a previously unopened package.

4.1.5 (The present paragraph 4.1.5 shall be deleted and replaced as follows:)

4.1.5 For single-pass welding of exposed, bare, unpainted applications of ASTM A588 steel requiring weld metal with atomspheric corrosion resistance and coloring characteristics similar to that of the base metal, the following variation from AWS D1.1 Table 4.1.4 may be made: (see 4.1.5.1 through 4.1.5.4). Table 4.1.4 footnote 2, shall be deleted; see 4.1.1.2.

4.1.6 (The present paragraph 4.1.6 shall be deleted and replaced with the following:)

4.1.6 Electroslag and electrogas welding shall not be used in FCMs.

4.2 Preheat/Interpass Temperature Requirements. (The first paragraph under 4.2 shall be deleted and replaced with the following:) All welding in FCMs shall be subject to the MINIMUM preheat and interpass temperatures specified in Table 4.2, as amended.

4.2.1 Welding shall not be done when the ambient temperature at the welding station is less than 50°F or when the plate surfaces are wet or when the welding operation is exposed to an air movement at the welding arc in excess of 5 miles per hour.

4.2.1.1 With external gas shielding, as in CO_2 shielded flux cored-arc welding, the welding operation shall not be exposed to wind or drafts exceeding 2 miles per hour.

4.2.2 The preheat/interpass temperature shall conform to the MINIMUM requirements of Table 4.2 (amended) for the higher yield-strength material in any given weld joint.

Quenched-and tempered (Q&T) steel shall conform to the preheat/interpass requirements specified as a function of welding-procedure energy input, KJ/in.

The preheat/interpass temperatures for as-rolled, control-rolled and normalized steels as specified in Table 4.2 (amended) shall be based on the tensile properties of the base metal as reported in the mill test reports and the tensile properties of the weld metal determined from all-weld-metal longitudinal-tensile specimens in weld-procedure-qualification testing. When run-off-plate production-weld-procedure testing is allowed in lieu of weld-procedure qualification, the weld-metal yield-strength shall be based on the tensile properties obtained in previous (4.1.1.5) weld-procedure qualification testing. The higher-strength material (weld or plate) shall control.

4.2.2.1 When the temperature of the base metal is below the temperature listed for the thickness of material being welded, it shall be preheated 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, with the preheat/interpass temperature measured on both surfaces of the plates being joined.

Temperature above the minimum shown may be required for highly restrained joints, but for Q&T steel the maximum preheat/interpass temperature shall not exceed the maximum specified in Table 4.2.

TABLE 4.2 (AMENDED)

PREHEAT/INTERPASS TEMPERATURE (°F)

AS-ROLLED, CONTROL-ROLLED AND NORMALIZED STEELS

Thickness of Thickest part at the joint	PLATE AND/OR WELD METAL YIELD STRENGTH		
	Up to 70 ksi	70 to 90 ksi	Over 90 ksi
INCHES	MIN	MIN	MIN
to 3/4, inc.	100	200	250
over 3/4 to 1-1/2	150	250	300
over 1-1/2 to 2-1/2	200	300	350
over 2-1/2	300	350	400

QUENCHED-AND-TEMPERED STEELS

	WELDING ENERGY INPUT, KJ/in.					
THICKNESS	30	40	50	70	90	110
3/8 to 1/2	150-300	100-200	100-200	100-200		
over 1/2 to 3/4	250-400	200-350	100-250	100-200	100-200	
over 3/4 to 1		250-400	250-400	150-300	100-200	100-200
over 1 to 2			250-400	250-400	200-350	200-300
over 2			300-450	300-450	300-450	300-400

NOTES: 1) When the temperature of the base metal is below the temperature listed for 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, with the preheat/interpass temperature measured on both sides of the plates being joined. Heat input when welding quenched and tempered steel shall not exceed the steel producers' recommendations.

2) Welding shall be carried to completion before the joint is allowed to cool below the minimum preheat/interpass temperature specified; i.e., the weld joint shall not drop below the minimum preheat/interpass temperature until the last weld pass of the joint is completed.

3) Welding a steel section which is at an initial temperature below 100°F may require localized preheating to remove moisture from the surface of the steel.

4.2.2.2 Welding shall be carried continuously to completion before the joint is allowed to cool below the minimum specified preheat/interpass temperature; i.e., the weld joint shall not drop below the specified minimum preheat/interpass temperature until the last weld pass of the joint is completed.

4.2.2.3 When postheating is required, as in paragraph 4.2.3, at no time shall the joint be allowed to cool below the MINIMUM specified preheat/interpass temperature before postheating is started.

4.2.3 For weld repair, the preheat/interpass temperature of Table 4.2, as amended, shall be used as specified in 3.7.7 together with a 450°F postheat for a minimum of one (1) hour for each inch of thickness in the cross section at the weld repair.

4.4 Arc Strikes. (The present paragraph 4.4 shall be deleted and replaced with the following:) Arc strikes outside the weld joint, on metal that will not be incorporated in a weld joint, may be cause for rejection of a member.

4.4.1 All arc strikes on surfaces carrying tensile stress shall be reported in writing to the Engineer.

4.4.1.1 Arc strikes on surfaces carrying tensile stress shall not be repaired without written authorization from the Engineer.

4.4.1.2 Repair of arc strikes shall be accomplished by grinding the area containing the arc strike to a minimum surface finish of ANSI 125.

4.4.1.3 The ground area shall be inspected by the dye-penetrant method and tested for heat-affected-zone hardness.

4.4.1.4 If the testing specified in 4.4.1.3 reveals cracking and/or hardness in excess of Rockwell C27, the area shall be weld repaired under the provisions of 3.7.3.

4.6 Groove-Weld Termination.

4.6.4 In FCMs, the attachment of extension bars and run-off plates shall require a written welding-procedure specification, including a detailed description of the inspection procedure after removal of the temporary welds.

4.6.4.1 The attachment of extension bars and run-off plates shall be accomplished using the consumables (AWS D1.1 Table 4.1.1) and the preheat/interpass temperatures (Table 4.2, as amended) specified for welds in FCMs.

4.7 Groove-Weld Backing.

4.7.1 (The present paragraph 4.7.1 shall be deleted and replaced with the following:) The steel used for backing welds perpendicular to the applied stress shall be removed, the joint backgouged and welding completed from the back side, except where not accessible. To facilitate removal of the backing, the backing shall be tacked in place from inside the joint; therefore, the welds holding the backing shall be incorporated in the groove weld being backed.

4.9 Electrodes for Shielded Metal Arc Welding.

4.9.2 (The present paragraph 4.9.2 shall be deleted and replaced with the following:) All electrodes having low-hydrogen coverings conforming to AWS A5.1 and AWS A5.5 shall be furnished in hermetically sealed containers. All shielded metal arc welding of FCMs shall be done using low-hydrogen-type electrodes.

4.9.2.1 Within one-half (1/2) hour of removal from hermetically sealed containers, all electrodes shall be dried for at least two (2) hours, but not to exceed four (4) hours, between 500 and 550°F before they are used. Electrodes not used immediately after drying shall be placed in a holding oven at 250 to 300°F and held in that temperature range continuously until used. Electrodes removed from the holding oven shall be used within the exposure times specified in Table 4.9.2.

TABLE 4.9.2

EXPOSURE TIME OUTSIDE THE HOLDING OVEN

Electrode Type	Maximum Time Before Use
E70, E80 & E90	1 hour
E100, E110 & E120	1/2 hour

Electrodes exposed for periods longer than specified shall be redried as follows:

(1) E100, E110 and E120 electrodes shall be dried not less than one (1) hour and not more than two (2) hours at a temperature between 700 and 800°F. The baking time shall not exceed two hours unless the manufacturer recommends longer baking time.

(2) E70, E80 and E90 electrodes shall be dried not less than two (2) hours and not more than three (3) hours at temperatures between 700 and 800°F. The baking time shall not exceed three hours unless the manufacturer recommends longer baking time.

(3) No electrode of any type shall be given more than one high-temperature bake as specified in (1) and (2) above. Electrode requiring a second bake under the provisions of 4.9.2.1 shall not be used in FCMs.

4.9.2.2 After drying as specified, electrodes shall be used within the maximum time specified in Table 4.9.2 or shall be stored in holding ovens as specified in paragraph 4.9.2 for electrodes removed from sealed containers.

4.9.2.3 Electrodes with classification E100XXX and higher, when used for welding ASTM A514/517 steels, shall be baked prior to use as in 4.9.2.1(1), regardless of packaging or time of removal from the package. Such electrodes for use in welding ASTM A514/517 steels may be baked only once for such use.

4.9.2.4 Electrodes which have been wet or physically damaged shall not be used.

4.9.2.5 Moisture content of electrode coatings shall not exceed the levels specified in 4.9.3.2. The Engineer may sample electrodes at random to determine moisture content.

Groove-weld joints welded with electrodes exceeding the limits of 4.9.3.2 shall be subjected to final nondestructive inspection not sooner than 96 hours after the completion of welding. When the groove-weld joints are stress relieved, the inspection may be done as soon as the weld cools to ambient temperature. Such welds found to be cracked may be rejected by the Engineer.

4.9.3 The Contractor shall maintain a file of manufacturer's certified test results of filler-metal qualification tests.

If the electrode to be used is not listed in this file or if the data contained therein are more than one year old, the Contractor shall furnish the Engineer with manufacturer's certified test results for each lot of electrodes to be used in the work prior to the start of fabrication.

The manufacturer's certification provides only for acceptance of the electrode. The production-welding procedure shall be qualified by the fabricator in accordance with the provisions of AWS 5.2, as amended, or verified in accordance with the provisions of 4.1.1.5.

4.9.3.1 For welding FCMs, the provisions of 4.1.2.3, 4.1.2.4 and 4.1.3.1 require consumable certification, package heat/lot identification and hydrogen determination.

4.9.3.2 The coverings of all low-hydrogen electrodes supplied in hermetically sealed containers shall have a maximum moisture content of 0.3 percent by weight for E70XX-X, E80XX-X and E90XX-X classifications and 0.1 percent by weight for E100XX-X, E110XX-X and E120XX-X classifications. Each container shall be so certified by the electrode manufacturer. The Engineer may sample electrodes at random to verify the moisture content.

4.12 Electrodes and Flux for Submerged Arc Welding.

4.12.1.1 A weld-procedure-qualification test shall be made for each thickness and each electrode/flux combination in accordance with AWS 5.2, as amended.

4.12.1.2 Alloy "active" fluxes shall not be used in groove welds or fillet welds with more than three passes.

4.12.1.3 For welding FCMs, the provisions of 4.1.2.3, 4.1.2.4 and 4.1.3.1 require consumable certification, package heat/lot/batch identification and hydrogen determination.

4.12.2 (The present paragraph 4.12.2 shall be deleted and replaced with the following:) The Contractor shall maintain a file of certified test results describing tests conducted by the manufacturer to qualify electrodes and flux for submerged-arc welding.

If the wire and flux combination to be used is not listed in this file or if the data contained therein is more than one year old, the Contractor shall furnish the Engineer with manufacturer's certified test results for each lot of electrode to be used in the work prior to the start of fabrication.

4.13 Condition of Flux.

4.13.1 Flux from packages more than six months old, or from damaged packages, or from opened packages that have not been stored at a minimum temperature of 250°F, shall be dried in a suitable oven for at least two hours between 500° and 550°F.

4.13.2 After removal from the drying oven, the flux shall be used immediately or shall be placed in holding ovens at 250°F. Flux not used within two hours after removal from the holding oven shall be re-dried, including flux in the machine hopper.

4.13.3 All flux for welding A514/517 steel shall be dried at least 2 hours between 775° and 825°F. Upon removal from the drying oven, the flux shall be used immediately or shall be placed in holding ovens at 250°F. Flux not used within one hour after removal from the holding oven shall be re-dried, including flux in the machine hopper.

4.13.4 When flux is "dried" as in 4.13.1 and 4.13.3, the drying operation shall be performed in a suitable oven with racks for spacing the trays, and each tray shall be no more than three (3) inches deep.

4.13.5 The flux from 10 percent of the packages used in welding FCMs, in a random sampling, shall be analyzed for moisture content on delivery from the manufacturer's plant and any packages not used within the specified six-month storage period shall be reanalyzed before use. The moisture content of the flux as received shall not exceed 0.2 percent by weight.

4.13.5.1 The flux manufacturer shall date each individual package of flux with the date of shipment. The six-month maximum storage shall start from that date.

4.13.5.2 The moisture content of the flux in the 10 percent as-received sampling, and after six-month storage shall be analyzed by the method of AWS A5.5-64T paragraph 25, Figure 10 and A1.9 for SMAW electrode coverings.

4.13.5.3 If the moisture content as indicated by the as-received sampling or after six-month storage exceeds the as-received maximum allowable moisture content of 4.13.5, the flux shall not be used in welding FCMs.

4.13.5.4 Groove-weld joints found to have been welded with flux improperly stored and/or exceeding the specified moisture limit shall be subject to final nondestructive inspection not sooner than 96 hours after the completion of welding. When the groove-weld joints are stress relieved, the inspection may be done as soon as the weld cools to ambient temperature. Such joints found to be cracked may be rejected by the Engineer.

4.14 Procedure for Submerged Arc Welding with a Single Electrode.

4.14.4 A shop-welded procedure-qualification test as specified in paragraph 4.1.1.4 may be required by the Engineer to demonstrate the performance of the wire-flux combination when welding with shop equipment using the qualified welding procedure.

4.15 Procedures for Submerged Arc Welding with Multiple Electrodes.

4.15.6 A shop-welded procedure-qualification test as specified in paragraph 4.1.1.4 may be required by the Engineer to demonstrate the performance of the wire-flux combination when welding with shop equipment using the qualified welding procedure.

4.16 Electrode and Shielding Gas for FCAW.

4.16.1.1 In FCMs, all welding with the flux-cored-arc welding process shall be restricted to the flat and horizontal positions.

4.16.2.1 In FCMs, the fabricator shall demonstrate conformance to 4.1.1.2 by testing per 5.2.1.

4.16.4.1 In FCMs, the Engineer will not accept evidence of prior testing, per 5.2.1.

4.16.5.1 For welding FCMs, the provisions of 4.1.2.3, 4.1.2.4 and 4.1.3.1 require consumable certification, package heat/lot identification and hydrogen determination.

4.16.5.2 The Contractor shall maintain a file of manufacturer's certified test results. If the FCAW electrode to be used in welding FCMs is not listed in this file or if the data contained therein is more than one year old, the Contractor shall furnish the Engineer with manufacturer's certified test results for each heat/lot of electrode to be used prior to the start of fabrication.

4.17 Shielding Gas.

4.17.1 For welding FCMs, the gas or gas mixture used in FCAW shielding shall be certified by the supplier (1) as suitable for the intended application and (2) as meeting the dew-point requirement of -40° or lower.

4.18 Procedures for Gas Shielded Flux-Cored Arc Welding.

4.18.1.1 (The present paragraph 4.18.1.1 shall be deleted and replaced with the following:) FCAW electrodes for use in FCMs shall be subject to a diffusible-hydrogen test conducted on the deposited weld metal in accordance with CSA Standard W487, Diffusible Hydrogen in Weld Steel and Low-Alloy Weld Metals: Test Method (Canadian Standard). The electrode manufacturer shall certify that the diffusible hydrogen in electrodes supplied for FCMs does not exceed the values in Table 4.18.1.1.

4.18.1.2 The Engineer may sample electrodes at random to determine the diffusible hydrogen content. Groove-weld joints found to have been welded with electrode exceeding the limits cited above shall be subjected to final nondestructive inspection not sooner than 96 hours after the completion of welding. Such joints found to be cracked may be rejected by the Engineer.

TABLE 4.18.1.1

DIFFUSIBLE HYDROGEN CONTENT OF WELD METAL

Electrode Classification	Max. Hydrogen ml/100g	
	Average	Single rdg.
E70T	8.0	10.0
E80T and E90T	5.0	6.3
E100T and E110T	3.0	3.8

5. QUALIFICATION

PART A - GENERAL REQUIREMENTS

5.1 Approved Procedures. The following changes in the AWS/AASHTO Structural Welding Code are mandatory for Fracture Critical Members (FCMs); paragraph numbers correspond to those of AWS D1.1-75, as revised.

5.1.1 (The present paragraph shall be deleted and replaced with the following:) Welding procedures which conform in all respects to the provisions of Section 2-Design of Welded Connections, Section 3-Workmanship, Section 4-Technique, as well as pertinent provisions of Section 8-Design of New Buildings, Section 9-Design of New Bridges, or Section 10-Design of New Tubular Structures, whichever are applicable, may be deemed prequalified and may be exempted from tests or qualification with the following exceptions:

5.1.1.1 In FCMs all materials and welding procedures shall be qualified prior to use. Welders, welding operators and tackers shall be qualified before welding structural steel. The Contractor, as his option, may combine qualification tests for materials, welding procedures and welding personnel, provided that all requirements pertaining to the respective testing are satisfied, as specified hereinafter.

5.1.1.2 The changes in welding procedure enumerated in AWS D1.1 paragraphs 5.5.2.1 through 5.5.2.5, as amended, shall be considered essential changes and shall require requalification under the provisions of 5.2, as amended.

5.1.1.3 Welding procedures for manual shielded metal-arc welding, which conform to the provisions in AWS D1.1 Section 1-General Provisions, Section 2-Design of Welded Connections, Section 3-Workmanship, Section 4-Techniques and Section 9-Design of New Bridges, will be considered as prequalified and will be exempt from tests for qualification under the following conditions:

Exemption of SMAW from weld-procedure qualification testing shall be allowed only if (1) the base-metal yield strength as certified in the mill test reports does not exceed 50 ksi, (2) the base-metal sulfur and phosphorus do not exceed 0.03 percent, (3) the base-metal carbon does not exceed 0.20 percent, and (4) the electrode is certified by the manufacturer for toughness down to -40°F, or lower.

Details of prequalified welding procedures to be used shall be furnished the Engineer prior to use. Such details shall be prepared by the manufacturer, fabricator or Contractor as a written procedure specification. A suggested form for providing the prequalification data is furnished in AWS D1.1 Appendix E.

5.1.2.1 When necessary to establish a welding procedure by qualification, such procedure shall be established as specified in this section and the procedure shall be recorded by the manufacturer, the fabricator, or the Contractor as a Procedure Specification. The welding-procedure specifications shall state the specific values of the essential variables of the welding operation, as required under 5.5.2.

5.2 Other Procedures. (The present paragraph shall be deleted and replaced as follows:) Except for the procedures exempted in 5.1, welding procedures which are to be employed in executing contract work under this code shall be qualified prior to use, by tests as prescribed in Part B of this Section.

5.2.1 With the exception of 5.1.1.3, the Engineer will not consider evidence of previous qualification of welding procedures for the following weld categories in FCMs:

(1) groove-weld butt joints in or contiguous to tension components,

(2) complete-penetration groove-weld T- and corner-joints in or contiguous to tension components where the welds are perpendicular to the applied stress, and

(3) fillet welds in or contiguous to tension components where the welds are perpendicular to the applied stress.

Weld-procedure qualification testing of complete-penetration groove-weld T- and corner-joints shall be done by making groove-weld butt joints of the same joint design (single bevel, double bevel, etc.) and using the thickness of the plate containing the weld in the T- or corner-joint. If the plate is less than one-inch thick, one-inch plate shall be used in testing. The steel shall be of the same grade/type as in the structure.

5.2.2 The Charpy V-notch impact MINIMUM values as specified herein are mandatory for qualifying the welding procedures used in groove-weld joints as specified above. The Charpy test results in groove welds shall conform to the requirements of Table. 4.1.1.2.

5.2.3 ASTM E399-76 may be used as an alternate test method for determining the fracture toughness of deposited weld metal in groove welds, testing at

the lowest anticipated service temperature (the LAST), with the test result as specified in 4.1.1.2.1 and 4.1.1.2.2.

5.3 Welders, Welding Operators and Tackers.

5.3.1 (The present paragraph shall be deleted and replaced as follows:) All welders, welding operators, and tackers to be employed in the fabrication of FCMs shall be qualified by tests as prescribed in Parts C, D and E of AWS D1.1 Section 5.

5.3.1.1 The Engineer may accept documented evidence of previous qualification of welders if (1) the tests were conducted within six months and (2) it can be documented that the welders, welding operators and/or tackers have been continuously employed using the particular welding process(es) and position(s) in question for three months or more in the six-month period since their previous qualification.

PART B - PROCEDURE QUALIFICATION

5.5 Limitation of Variables.

5.5.1 (The present paragraph shall be deleted and replaced as follows:) The following rules apply to those procedures which must be qualified under 5.1 and/or 5.2 or by contract specification. The written welding procedure specifications required under both 5.1 and 5.2 shall be the basis of the "limitation of variables" described in 5.5.2.1 through 5.5.2.4.

5.5.1.1 (The present paragraph shall be deleted and replaced as follows:) Qualification of a welding procedure shall be accomplished

using base metal of the same ASTM/AASHTO Specification type and grade as that to be used in the bridge.

5.5.1.2 (The present paragraph shall be deleted and replaced as follows:) In weld-procedure qualification, with plate up to 90 ksi yield strength, a change in plate thickness outside the limits of 0.5.T to 1.5T, where T is the thickness used for procedure qualification, shall be considered an essential change and shall require establishing a new procedure by qualification.

In weld-procedure qualification, with plate over 90 ksi yield strength a change in the plate thickness used in procedure qualification of more than one-half (1/2 inch shall be considered an essential change and shall require establishing a new procedure by qualification.

5.5.1.3 (The present paragraph shall be deleted and replaced as follows:) Qualification of a welding procedure shall be accomplished using welding consumables of the same heat, lot and batch as to be used in the FCMs. Each shipment of consumables shall be accompanied by the producer's certification as to heat/lot/batch in the shipment in accord with 4.1.2.5. A change in heat, lot and/or batch shall be considered an essential change and shall require establishing a new procedure by qualification. The certified chemistry for each heat, lot and batch of consumables shall include the hydrogen (1) in the wire, and (2) the moisture content of the coatings and/or fluxes, or the diffusible hydrogen in deposited weld metal, as specified in 4.1.3.1, 4.9.3.2, 4.13.4 and 4.18.1.

5.5.1.5 (The present paragraph 5.5.1.5 shall be deleted and replaced with the following:) In preparing the welding-procedure specification, the Contractor shall report the specific values for the essential variables that are enumerated in 5.5.2. The suggested form for showing the information required in the welding-procedure specification is given in AWS D1.1 Appendix E.

5.6 Types of Tests and Purposes.

(The present Section 5.6 shall be deleted and replaced as follows:)

5.6 Weld-Procedure Qualification Tests. The types of inspections and tests specified herein shall be performed on each procedure test weld and on specimens removed from it. The results of these inspections and tests shall verify the mechanical properties and soundness of welded joints. No specimen removed from a test weld shall be subjected to any post-weld thermal treatment prior to testing except as a provision of the written weld-procedure specification.

5.6.1 Qualification of groove-weld procedures shall be based upon the results of mechanical tests and chemical analysis of test specimens machined from welds made using the procedure qualification test plate for FCMs detailed in Figures 5.6.1a through d. All weld passes shall be made with the same welding conditions that are to be used in the structure. Test specimens shall be removed and prepared for testing as described in 5.10. All mechanical testing shall conform to the requirements of ASTM A370.

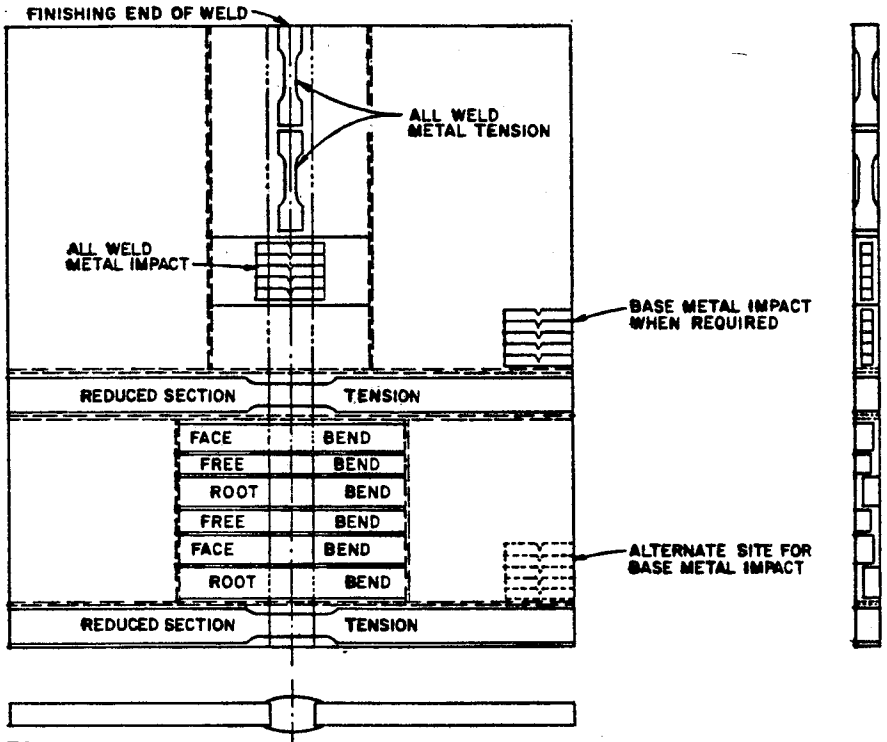


FIGURE 5.6.1.a Weld Procedure Qualification Test - 1/2 in. or less.

NOTES: 1) THE ENDS OF TENSION AND BEND SPECIMENS MAY BE IN A FLAME-CUT EDGE, BUT THE SIDES OF TENSION AND BEND SPECIMENS SHALL BE NO CLOSER THAN 1/2 IN. TO A FLAME-CUT EDGE.

2) THE SIZE AND LOCATION OF ALL-WELD-METAL TENSION SPECIMENS SHALL BE SELECTED SUCH THAT THE SPECIMEN WILL BE THE LARGEST ASTM E8 SIZE PERMITTING THE REDUCED SECTION OF THE SPECIMEN TO BE ALL WELD METAL.

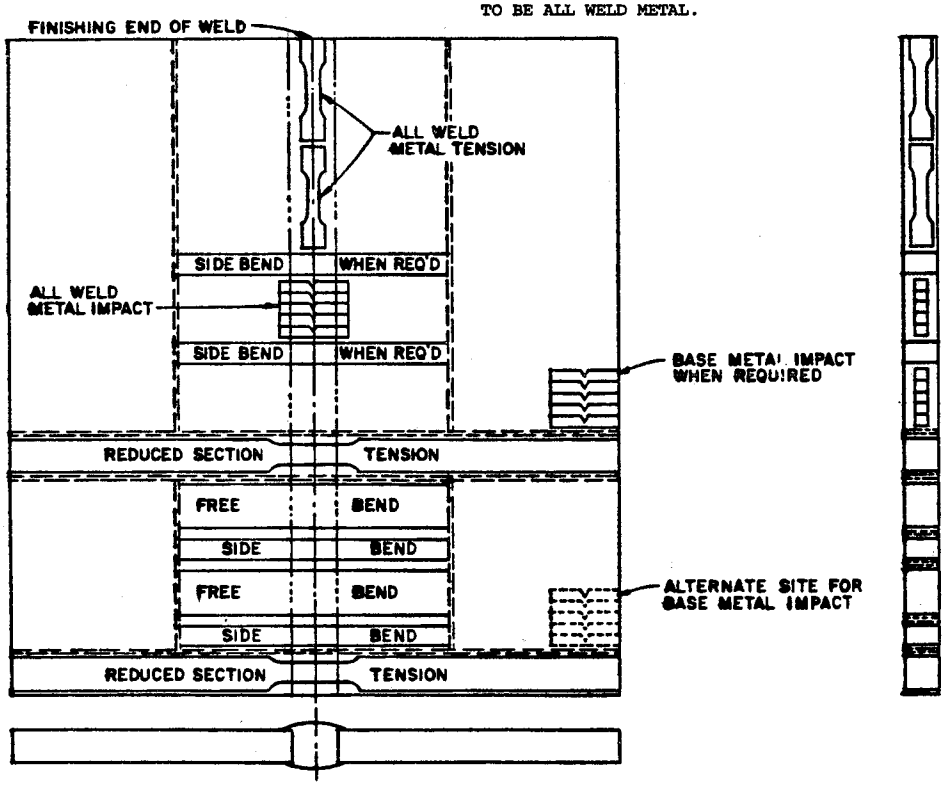


FIGURE 5.6.1.b
Weld Procedure Qualification Test Plate - over 1/2 to 1 1/8 in.

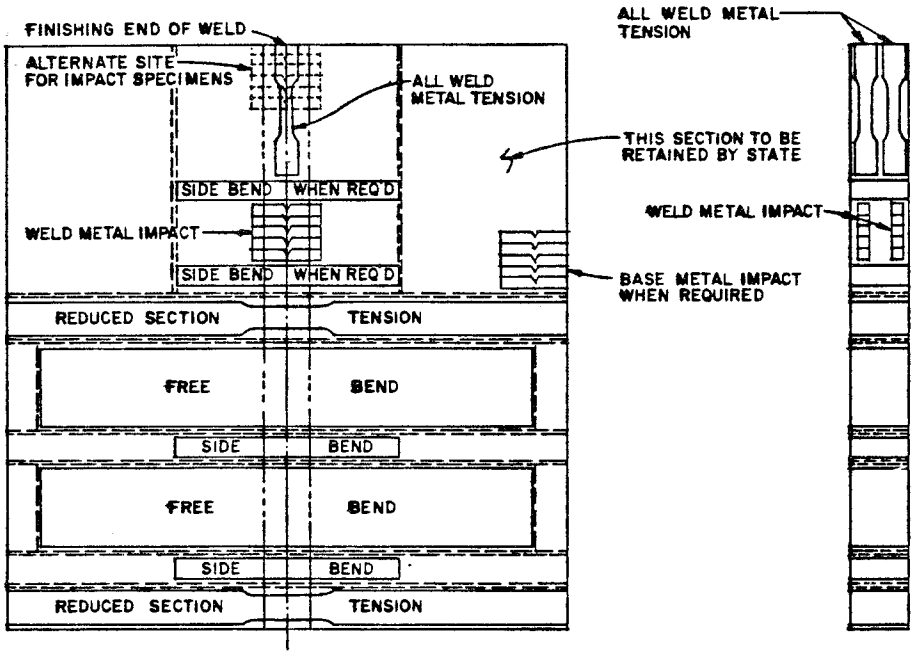


FIGURE 5.6.1.c
Weld Procedure Qualification Test Plate - over 1 1/8 to 2 in.

NOTES: 1) THE ENDS OF TENSION AND BEND SPECIMENS MAY BE IN A FLAME-CUT EDGE, BUT THE SIDES OF TENSION AND BEND SPECIMENS SHALL BE NO CLOSER THAN 1/2 IN. TO A FLAME-CUT EDGE.

2) THE SIZE AND LOCATION OF ALL-WELD-METAL TENSION SPECIMENS SHALL BE SELECTED SUCH THAT THE SPECIMEN WILL BE THE LARGEST ASTM E8 SIZE PERMITTING THE REDUCED SECTION OF THE SPECIMEN TO BE ALL WELD METAL.

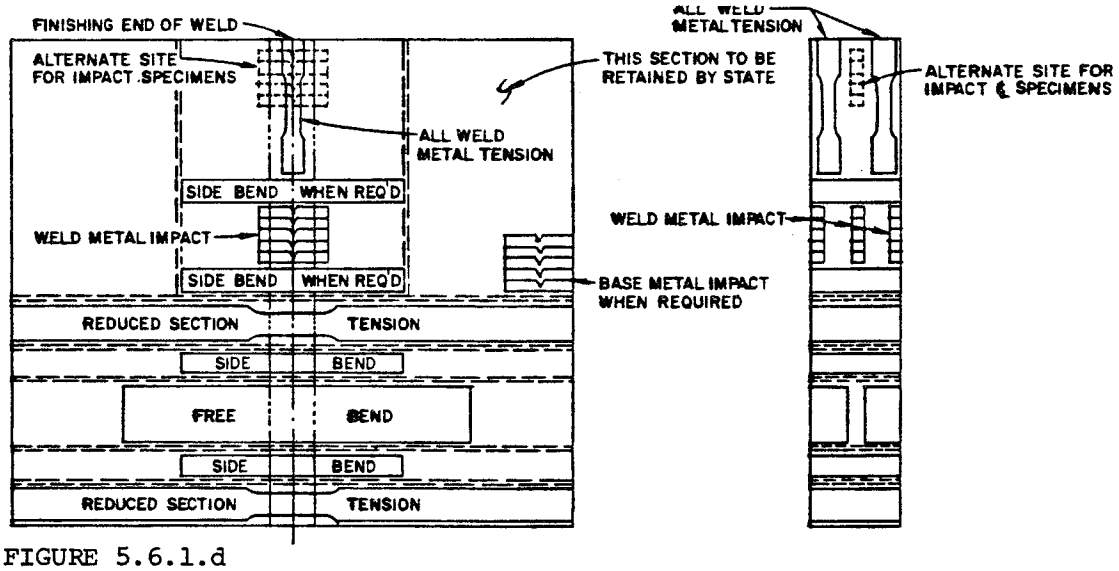


FIGURE 5.6.1.d
Weld Procedure Qualification Test Plate - over 2 in.

5.6.1.1 For groove welds the following tests shall be performed as specified herein:

(1) Reduced-section tension test (for tensile strength)

(2) Root-bend test (for soundness)

(3) Face-bend test (for soundness)

(4) Side bend test (for soundness)

(5) All-weld-metal test (weld-metal tensile)

(6) Impact test (weld-metal toughness)

(7) Free bend test (for ductility)

(8) Radiographic test (for soundness)

(9) Ultrasonic test (for soundness)

5.6.1.2 For fillet welds the following tests shall be performed as specified herein:

(1) Macroetch test (for soundness)

(2) Fracture test (for soundness)

(3) T-Bend test (for ductility)

(4) Impact test (weld-metal toughness)

5.7 Base Metal and Its Preparation.

(The present Section 5.7 shall be deleted and replaced with the following:)

5.7 Test Welds. The base metal and its preparation for welding procedure test welds shall comply with the Procedure Specification. Visual requirements shall conform to the requirements in Section 6, as amended. For all types of welded joints, the length of the weld in the test weld and the dimensions of the base metal utilized in the test weld shall be sufficient

for the proper preparation of the test specimen from the test weld and shall conform to the following:

5.7.1 Test plates for preparation of groove test welds shall be aligned and restrained or welded with pass sequence so balanced that warping due to welding will not exceed 5 degrees. Failure to meet this requirement will be cause for rejection. Each test weld shall terminate in run-over joint blocks.

5.7.2 For testing groove welds, one procedure test shall be prepared for each welding procedure and position, using plate of the thicknesses specified herein and the same grade/type to be used in production with that procedure.

5.7.3 One test fillet weld shall be prepared for each position of each procedure in both the largest single-pass fillet weld and the largest multiple-pass fillet weld to be used in that position with their respective procedures. The base metals forming the base and stem of the test fillet weld shall be of the highest strength steel to be used with the procedure for the base and stem respectively. When a procedure specification is to employ a machine to make two welds simultaneously, a test sample consisting of two test fillet welds made simultaneously shall be prepared and tested. For fillet-weld toughness, see 5.10.3.4.

5.7.4 No test weld shall be subjected to any postweld thermal treatment prior to the removal and testing of specimens. Postheating or postweld thermal stress relieving as part of the welding-procedure specification does not constitute a postweld thermal treatment for purposes of this restriction.

5.8 Position of Test Welds.

5.8.1 (The present paragraph 5.8.1 shall be deleted and replaced as follows:) All procedure test welds including the T- and corner-joint groove weld qualification testing of 5.10.1.2 shall be fabricated in positions to be encountered in actual fabrication. Welds shall be classified as being 1) Flat, 2) Horizontal, 3) Vertical progressing upward, 4) Vertical progressing downward, or 5) Overheat. Welding positions shall be as detailed in AWS D1.1 Figures 5.8.1a, 5.8.1b, 5.8.1.1 and 5.8.1.3.

Each procedure shall be tested for each position for which it is to be qualified; as set forth herein.

(1) For groove weld testing, test plates shall be welded in the positions as shown in AWS D1.1 Figure 5.8.1a.

(2) For fillet weld testing, test plates shall be welded in the positions as shown in AWS D1.1 Figure 5.8.1b.

5.9 Joint Welding Procedure. (The present paragraph 5.9 shall be deleted and replaced as follows:) The joint welding procedure in production shall comply in all respects with the groove- and fillet-welding procedure specifications as developed from weld-procedure qualification testing, within the limits of 5.5, as amended.

TABLE 5.10.1

WELD PROCEDURE QUALIFICATION TESTS FOR GROOVE WELDS

TEST PLATE THICKNESS	RT AND UT	REDUCED SECTION TENSION	ALL WELD METAL TENSION	ROOT BEND	FACE BEND	SIDE BEND	FREE BEND	WELD METAL IMPACT
To 1/2"	BOTH	2[a]	2[b]	2[c]	2[c]	--	2[e]	5
Over 1/2"	BOTH	2[a]	2[b]	--	--	4[d]	2[e]	5

a. See AWS D1.1 Figure 5.10.1.3f

b. See AWS D1.1 Figure 5.10.1.3g

c. See AWS D1.1 Figure 5.10.1.3h

d. See AWS D1.1 Figure 5.10.1.3j

e. See Figure 5.10.1.1

5.10 Test Specimens: Number, Type, Preparation and Inspection.

5.10.1 Complete-Penetration Groove Welds.

5.10.1.1 (The present paragrpah 5.10.1.1 shall be deleted and replaced as follows:) The following inspections and tests shall be performed on the procedure test welds:

Radiographic and ultrasonic inspection shall be conducted on each groove test weld before any test specimens are removed from the test weld. The results shall be reported to the Engineer.

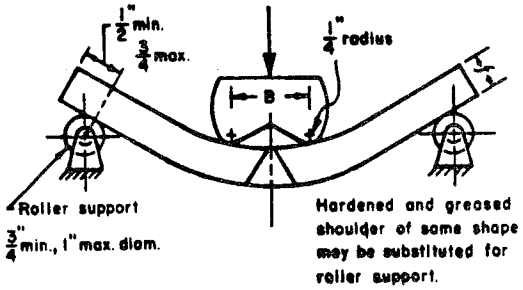
If the inspected test weld meets the requirements of AWS D1.1 Section 6, as amended, specimens shall be removed from the test weld in accordance with the requirements of Table 5.10.1 and the details shown in Figures AWS Figures 5.10.1.3f through j, and prepared as follows:

(1) Reduced-section weld-transverse tension test specimens shall be prepared in accordance with the details shown in AWS Figure 5.10.1.3f.

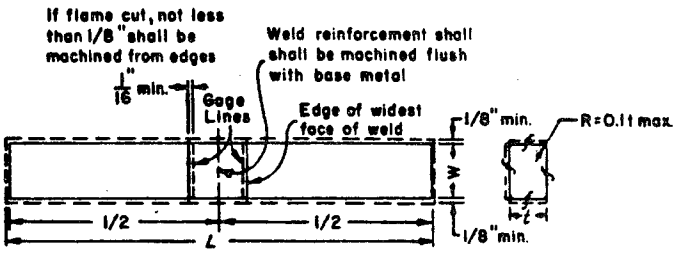
(2) Root and face-bend test specimens shall be prepared in accordance with the details shown in AWS Figure 5.10.1.3h.

(3) Side-bend test specimens shall be prepared in accordance with the details shown in AWS Figure 5.10.1.3j.

(4) Free-bend test specimens shall be prepared in accordance with the details shown in Figure 5.10.1.1.



INITIAL BEND FOR FREE-BEND SPECIMENS



Dimensions

T, in.	1/2 or less	9/16	5/8	11/16	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
t, in.	3/8	9/16	5/8	11/16	3/4	7/8	1	1	1 1/8	1 1/4	1 3/8
W, in.	9/16	27/32	15/16	1 1/32	1 1/8	1 5/16	1 1/2	1 1/2	1 11/16	1 7/8	2 1/16
L min, in.	6 3/8	8 3/8	9 1/8	9 7/8	10 5/8	11 3/8	12 3/8	12 3/8	13 1/8	13 7/8	14 5/8
B* min, in.	1 1/4	2	2	2	2	2	2	2	2	2	2

T, in.	1 5/8	1 3/4	2	2 1/4	2 1/2	2 3/4	3
t, in.	1 1/2	1 5/8	1 7/8	1	1 1/8	1 1/4	1 3/8
W, in.	2 1/4	2 7/16	2 13/16	1 1/2	1 11/16	1 7/8	2 1/16
L min, in.	15 3/8	16 3/8	17 3/8	12 3/8	13 1/8	13 7/8	14 5/8
B* min, in.	2	2	2	2	2	2	2

Figure 5.10.1.1 FREE-BEND SPECIMEN

NOTE 1: The length L is not mandatory.
2: If desired, the edges of the specimen may be prepared by machine flame cutting followed by rounding of the corners with a file, though this may be a more severe test.
3: T is the test-plate thickness and t is the specimen thickness (W= 1 1/2 t).

(5) The weld-longitudinal, all-weld-metal tension test specimen shall be prepared in accordance with the details shown in AWS Figure 5.10.1.3g.

(6) Impact test specimens of weld metal shall be prepared in accordance with the details shown in Figure 7 of ASTM Standard Methods for Notch Bar Impact Testing of Metallic Materials E23 for Type A Charpy (Simple Beam) Impact specimens. The use of subsize specimens shall be limited to specimens 0.295-inch in width and restricted to test welds fabricated from plates less than 7/16-inch thick or fillets per 5.10.3.4.

In accord with ASTM E23, Section 6, Charpy machines used in testing plate and welds in FCMs shall be proof tested with standardized specimens every six (6) months. Documentation based on the AMMRC report of evaluation shall be submitted to the Engineer prior to testing.

(7) ASTM E399-74 compact tension specimen (CTS) testing may be done in lieu of weld-metal Charpy impact testing (see 5.11.7.2).

5.10.1.2 (The present paragraph shall be deleted and replaced as follows:) Weld-procedure-qualification testing for groove welds in T- or corner-joints shall be butt joints having the same groove

configuration as the T- or corner-joint to be used in construction. The thickness of plate used in making the butt weld shall be that of the plate containing the weld in the T- or corner-joint.

5.10.3 Fillet welds. (The present paragraph 5.10.3 shall be deleted and replaced as follows:)

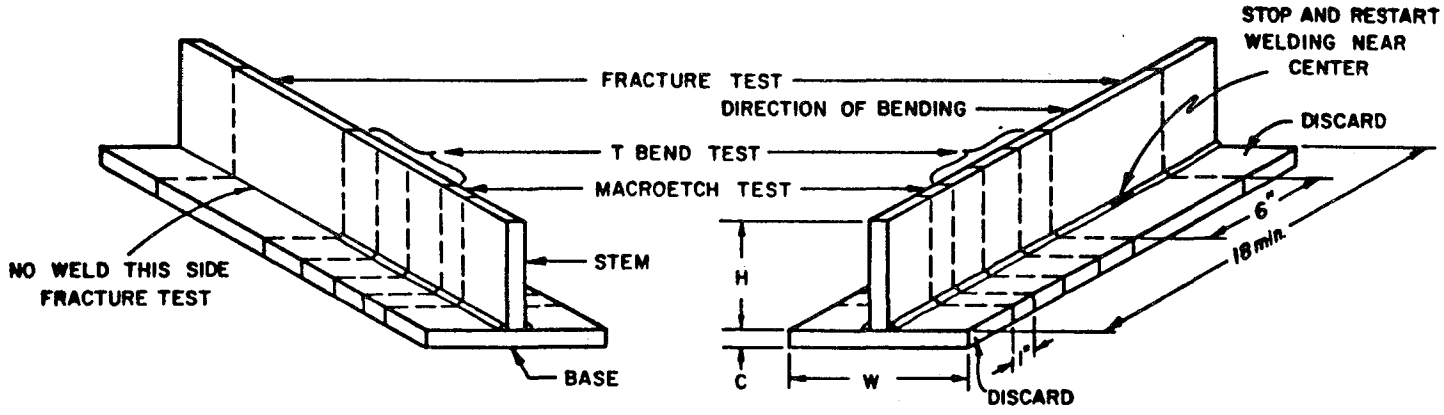
5.10.3.1 T-bend test specimens shall be prepared in accordance with the details shown in Figures 5.10.3.1A and 5.10.3.1B.

5.10.3.2 Macroetch test specimens shall be prepared by having the cut ends of the specimen machined parallel and one face of the specimen surface ground to 250 rms (60 grit).

5.10.3.3 The fracture test specimen shall be tested as cut from the test weld. If the specimen is fillet welded or tack welded on the side opposite the test weld, the fillet or tack weld shall be sawed through the throat to permit testing. If the weld is too heavy to be readily fractured at the root; the weld may be weakened by sawing into the crown to a depth not greater than one-third (1/3) the throat dimension.

5.10.3.4 Incomplete-penetration fillet welds may be used in lieu of complete-penetration groove-weld T-joints when weld-procedure-qualification testing is in accordance with Figure 5.10.3.4 (see 2.15.12.3 and 4.1.1.2.7).

5.10.4.1 In testing groove- and fillet-welding procedures for FCMs, there shall be no aging of either welds or test specimens unless the aging treatment is part of the weld-procedure specification to be used in production welding.



PREPARATION OF TEST SPECIMENS

Specimens may be sawed, machined, or flame cut from welded test joint.
The ends of etched specimen shall be smooth for etching.

DIMENSIONS FOR PROCEDURE TEST

Base Thickness	C	Design Section, but not less than 2S or 3/4" or more than 2"
Stem Height	H	8B but not less than 6"
Base Width	W	4C but not less than 7"
Filet Weld Leg Size	S	Design Section
Stem Thickness	B	Design Section, but not over 2S or 3/4"

FILLET WELD PROCEDURE TEST SAMPLE

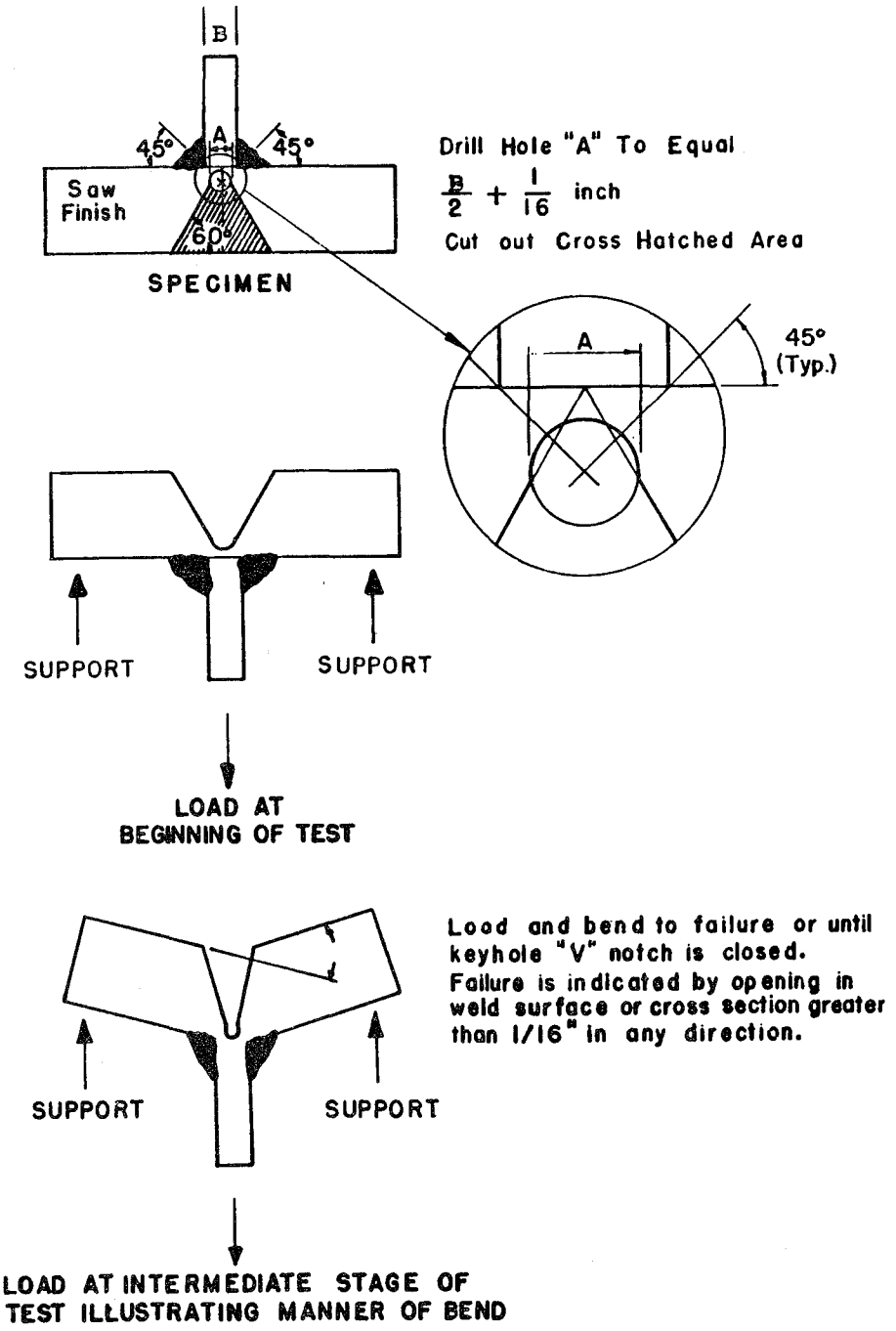


FIGURE 5.10.3.1 - FILLET WELD KEYHOLE "T" BEND TEST

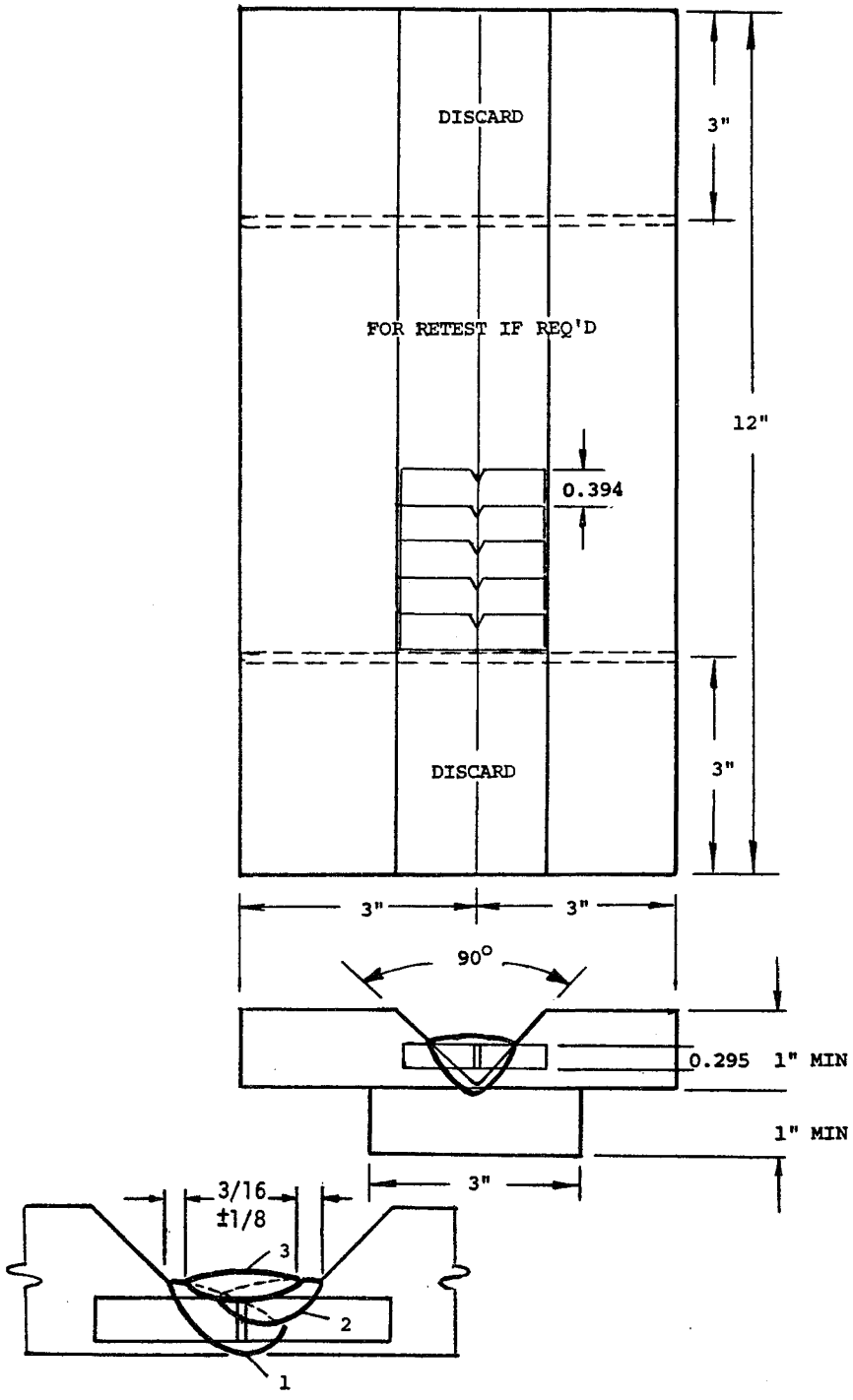


Figure 5.10.3.4 - Weld-Procedure-Qualification Test for Fillet Welds (see NOTES, p. 81).

FIGURE 5.10.3.4 NOTES

(1) For purposes of determining the toughness of the weld metal in fillet joints, the weld shall be deposited in a groove-weld butt joint with a 90 degree included angle, in the position to be used in production;

(2) in fillet weld-procedure-qualification testing for toughness, the electrode diameter, the energy input (amps, volts, and arc travel speed), preheat/interpass temperature, consumables, and all other variables under AWS D1.1 paragraph 5.5.2 shall be the same as proposed for production welding;

(3) the steel and backing shall be of the same grade/type as that to be used in production;

(4) multiple-pass fillets shall be deposited in three (3) passes where (a) the first and second passes may be deposited as two separate passes or with two electrodes in a single pass; (b) the third pass shall be deposited after the joint has cooled to within 100°F of the MINIMUM interpass temperature of 4.2, as amended; and (c) the third pass shall not penetrate the base metal at any point;

(5) for multipass fillet welds, a change in sequence and/or positioning of the weld passes within the joint shall be considered an essential change under AWS D1.1 paragraph 5.5.2;

(6) the Charpy impact specimen shall be the ASTM E23-72 5 mm or 7.5 mm subsize specimen positioned with the notch centered on the weld (in the plane of the throat of the "fillet"), and with the notch oriented so as to drive the crack down the length of the "fillet".

5.11 Method of Testing Specimens.

5.11.2 Macroetch test. (The present paragraph shall be deleted and replaced as follows:)

5.11.2.1 Each macroetch specimen shall have its ground surface etched by being immersed or swabbed with 25 percent nitric acid solution until the outlines of the weld metal and the heat-affected zone are clearly visible. The specimen shall then be rinsed in clear water or some suitable drying agent and dried in a stream of air without touching the etched surface. As an alternative, the etched specimen may be scrubbed under a stream of water with a cotton or lint swab, rinsed with a suitable drying agent and dried in a stream of air. This etching operation shall be repeated as necessary until an outline of the weld and heat-affected zone of readable quality is produced. The size, penetration, and soundness of the test weld will be evaluated from the profile, penetration, grain size, and number of inclusions in the etched cross section.

5.11.3 (The present paragraph shall be deleted and replaced as follows:) Each root-, face-, or side-bend test specimen shall be bent in a jig with the dimensions of AWS D1.1 Fig. 5.27.1. The specimen shall be placed on the female member of the jig with the weld at midspan. The root-bend specimen shall be placed with the root of the weld directed toward the gap. Face-bend specimens shall be placed with the face of the weld directed toward the gap. Side-bend specimens shall be placed with that side showing the greater defects, if any, directed toward the gap.

The plunger shall force the specimen into the die until the specimen becomes U-shaped. The weld and heat-affected zones shall be centered and completely within the bent portion of the specimen after testing. When using the wraparound jig, the specimen shall be firmly clamped on one end so that there is no sliding of the specimen during the bending operation. The weld and heat-affected zones shall be completely in the bent portion of the specimen after testing. Test specimens shall be removed from the jig when the outer roll has been moved 180 degrees from the starting point.

5.11.4 All-weld-metal tension test. (The present paragraph shall be deleted and replaced as follows:) The yield strength of the weld metal deposited in the procedure-qualification test weldment shall be determined from a standard small-size round tension test specimen (ASTM A370-74, Figure 5) centered in the weld deposit as shown in Figures 5.6.1a-d. For welds 1 1/8-inch or thicker, duplicate specimens shall be tested and averaged, one from each face of the weld joint.

Each all-weld-metal tension test specimen shall be tested in accordance with the procedure set forth in the ASTM Standard Methods of Tension Testing Metallic Materials, Designation: E8. The ultimate strength and the yield strength (0.2 percent offset) or point (0.5 percent total strain) of the weld metal deposit shall be determined by the yield method specified for the AWS class of the electrodes used to make the weld. The tensile results shall be recorded in pounds per square inch and the elongation and reduction of area of the weld metal deposit shall be obtained in percent values.

5.11.5 (The present paragraph shall be deleted and replaced as follows:)

5.11.5 Free-bend testing.

5.11.5.1 Each free-bend test specimen shall be lightly scribed on the face of the welds with a pair of gage lines perpendicular to the long axis of the bend specimen. The gage length shall be approximately 1/8 inch less than the width of the face of the weld and shall be measured in inches to the nearest 0.01 inch. Each specimen may be bent initially by the use of a fixture complying with the requirements of Figure 5.10.1.1. The surface of the specimen containing the gage lines shall be directed toward the supports. The weld shall be at midspan of both supports and the loading block.

Alternatively, the initial bend may be made by holding each specimen in the jaws of a vice with 1/3 the length of the specimen projecting from the jaws, then bending the specimen away from the gage lines through an angle from 30 to 45 degrees by blows of a hammer. The other end of the specimen shall be bent in the same way. In order that the final bends shall be centered on the weld, the initial bends shall be symmetrical with respect to the weld, and both ends shall be bent through the same angle. The initial bend may also be started at the weld by placing the specimen in the guided-bend test jig shown in Figure 5.10.1.1.

5.11.5.2 After the initial bend has been made, compressive forces shall be applied to the ends of the specimen in order to bend the weld by continuously decreasing the distance between the ends. (Any convenient means such as a vise or a testing machine may be

used for the final bend.) When either a crack or other open defect exceeding 1/16-inch in any direction appears on the convex face of the specimen, the load shall immediately be removed. Cracks occuring on the corners of the specimen during testing will not be considered.

5.11.5.3 The elongation shall be determined by measuring the minimum distance between the gage lines, along the convex surface of the weld to the nearest 0.01-inch and subtracting the initial gage length. The percent elongation shall be obtained by dividing the elongation by the initial gage length and multiplying by 100 in order to determine the ductility of the test joint.

5.11.6 Nondestructive testing. (This paragraph shall be deleted and replaced as follows:) The radiographic and ultrasonic testing procedure and technique shall be as specified in AWS D1.1 Section 6, as amended.

5.11.7 Weld-toughness testing.

5.11.7.1 The Charpy V-notch impact tests of groove welds shall be conducted in accordance with the requirements of ASTM A370, with the following special provisions:

The specimens shall be cut with the longitudinal axis of the test piece transverse to the weld and the V-notch perpendicular to the as-rolled plate surface and located as near as practicable to the weld centerline.

In plate less than 1 1/8-inch thick, the weld test pieces shall be taken from the midthickness of the plate. The use of subsize specimens is not permitted for testing welds in plate 7/16-inch and thicker. When limited by lesser plate thickness (and in testing fillet welds), the specimen width may be reduced to 0.295± 0.001 (the specimen depth remains at 0.394). When impact tests are conducted on 0.295-inch-wide specimens, the energy level shall be 75 percent of the value specified for full-width 10 x 10 mm specimens.

In plate 1 1/8 to 2-inches thick, tests shall be made at both surfaces.

In plate over 2-inches thick, tests shall be made at both surface positions as well as at the midthickness position.

5.11.7.2 In lieu of Charpy impact testing groove welds, ASTM E399-74 compact testing or bend testing of groove welds may be done with the following special provisions:

Deposited weld metal shall be tested for plane-strain fracture toughness, K_{Ic}, using the weld-procedure qualification plate as a source of test material. Specimens for duplicate testing shall be cut with the path of fracture centered on the weld deposit and longitudinal to the weld. The test-piece thickness shall be one (1) inch, and for plate in the range of 1- to 2-inch thickness the duplicate test pieces shall be taken from midthickness of the plate. For plate over 2-inches thick, the test pieces shall be taken from the quarter-point thickness position.

For compact-tension tests involving non-linear (elastic-plastic) behavior, the fracture toughness shall be calculated by elastic-plastic techniques based on maximum load as the measuring point.

5.11.7.3 Nil-ductility transition (NDT) temperature tests of groove welds shall be conducted in accordance with the requirements of ASTM E208, with the following special provisions:

P-3 type specimens shall be cut with the longitudinal axis of the test piece transverse to the weld, and the crack-starter weld bead in the plane of the face of the test weld (reinforcement removed). In groove-welds 1 1/2-inches and thicker, both face and root sides of the weld shall be tested and the NDT based on triplicate specimens from each face, tested for "no-break" performance at the specified NDT temperature plus 10°F. In groove welds less than 1 1/2-inches thick, three specimens shall be prepared from one face of the weld.

5.12 Test Results Required.

5.12.1.2.1 For the free-bend test, elongation shall not be less than 25 percent for welds in steels of yield strength up to 90 ksi, or less than 17 percent in welds in steels over 90 ksi yield strength.

5.12.1.4 All-Weld-Metal Tension Test. The tensile properties measured in all-weld-metal testing of groove welds shall conform to the following requirements:

The minimum yield strength of weld metal deposited in weld-procedure-qualification testing shall be the minimum yield-strength of the base-metal grade/type being joined, with the following exception: In partial-penetration groove welds, the yield strength of the deposited weld metal may be lower than that of the base metal providing the effective weld-throat is sufficient to develop the design strength as demonstrated by sectioning and macroetch testing.

The maximum yield strength of weld metal deposited in weld-procedure-qualification testing shall not exceed the following values:

YIELD STRENGTH (ksi)

BASE METAL GRADE/TYPE	Weld-METAL MAXIMUM
over 90 to 100	110
over 70 to 90	100
over 50 to 70	90
over 40 to 50	80

5.12.1.5 (The present paragraph 5.12.1.5 shall be deleted; see 5.10.1.1.)

5.12.1.6 Weld-Toughness Tests. The Charpy impact testing of groove-welds shall produce an average of three test values not less than the minimum energy level specified in Table 4.1.1.2.

If ASTM E399 testing is used as an alternative to Charpy V-notch impact testing of groove welds, the minimum acceptable toughness at the LAST as determined in this testing shall be a function of thickness and weld yield strength as specified in 4.1.1.2.1.

5.12.1.7 For the fillet-weld test, in the fracture test, the fractured specimen shall exhibit no incomplete fusion to the base metal, lack of penetration cracking, or any inclusion or porosity larger than 3/32-inch in greatest dimension. The sum of the greatest dimensions of all internal inclusions and porosity in any linear inch of weld shall not exceed 3/8 inch.

In the T-bend test, the fillet weld shall be capable of meeting the bending requirements listed in Tables 5.12.1.7a, b and c.

In the groove-weld test of fillet-weld procedure, the minimum acceptable impact values at the LAST shall be as specified in the following table:

FILLET SIZE (in.)	CHARPY SIZE	ENERGY REQUIRED (FT-LB) E60, 70, 80[a]	ENERGY REQUIRED (FT-LB) E90, 100, 110[b]
5/16 to 3/8	0.197 (5 mm)	15	25
7/16 to 1/2	0.295 (7.5 mm)	25	35
9/16 and up	0.394 (10 mm)	35	45

(a) filler classification including F6X-EXXX, F7X-EXXX and F8X-EXXX

(b) filler classification including F10X-EXXX and F11X-EXXX

5.13 Recording and Certification of Procedure-Qualification Test Results. (The present paragraph 5.13 shall be deleted and replaced as follows:) The Contractor shall furnish the Engineer four copies of certified reports from a recognized testing agency showing the results of all tests performed to qualify a welding procedure, including any unsatisfactory procedure tests. Each report shall include:

(1) The name and address of the testing agency.

(2) Date and report number.

(3) Name and social security number of the welder or operator who made the test plate.

(4) The number or mark stamped or painted on the test plate to verify its identification in a test report. (Usually the inspector's lot number or the testing lab's report number.)

(5) All details of the welding procedure used to make the test plate.

(6) Copy of the AMMRC Proof Test Certification and test results for the Charpy V-notch (CVN) impact machine(s) used in testing. For FCMs, CVN-impact testing machines shall be Proof tested per ASTM E23-72 paragraph 6.1 every six months. Data from a machine not proof-tested within six months of the date of the weld-procedure qualification testing will be rejected by the Engineer.

(7) Test results and conclusions.

(8) The name of the State Inspector witnessing the welding and testing.

(9) The signature and registration or identification number of the engineer who was in responsible charge of the preparation and testing of specimens and the interpretation of the test data.

This engineer shall be competent in the field of mechanical testing of structural metals and shall be registered in the State where the tests are performed or equally qualified if the tests are performed in a foreign country.

The engineer's signature on the test report shall certify only that the preparation and testing of the specimens removed from the test weld and the interpretation of test results are in accordance with these specifications except that if the testing agency has been assigned to inspect the weld preparation also, the testing agency's engineer may then certify weld preparation as well as specimen testing.

The testing agency shall notify the Engineer of welding or testing at least 12 hours in advance. The Engineer may require test specimens to be furnished to him for review after testing. A procedure shall be considered qualified when the Engineer signs and returns one copy of the test report to the Contractor. Any procedure failing to pass a procedure test shall not be retested until a significant change has been made in procedure.

5.14 Retests

5.14.1 If one (1) test specimen fails to meet the test requirement specified above, two (2) retests for that particular type of test specimen may be performed with specimens cut from the same procedure test plate. The results of both retest specimens shall meet the test requirements.

5.14.2 If more than one test specimen fails to meet the test requirement in the first instance, the weld procedure is disqualified and must be redone. In the E208 NDT determination, there shall be no retesting.

TABLE 5.12.1.7a

Fillet Weld T-Bend Angles

Minimum Acceptable Angles of Bend for T-Bend Tests of Single-Pass Fillet Welds Made with E-70 Grade Electrode materials on steels with minimum specified yields less than 60 ksi.

Stem Thickness	Fillet Weld Size					
	1/4	5/16	3/8	1/2	5/8	3/4
1/4	25°					
5/16	22°	25°				
3/8	20°	23°	25°			
7/16	19°	21°	23°			
1/2	17°	20°	22°	25°		
9/16	16°	18°	20°	24°		
5/8	15°	17°	19°	22°	25°	
11/16	14°	16°	18°	21°	24°	
3/4	13°	15°	17°	20°	23°	25°
7/8	12°	14°	16°	19°	21°	23°

TABLE 5.12.1.7b

Fillet Weld T-Bend Angles

Minimum Acceptable Angles of Bend for T-Bend Test of Single-Pass Fillet Welds Made with E-70 Grade Electrode materials on steels with minimum specified yields of 60 ksi or greater* or Fillet Welds made with E80 Grade Electrodes on steels with minimum specified yields less than 60 ksi.

Stem Thickness	Fillet Weld Size					
	1/4	5/16	3/8	1/2	5/8	3/4
1/4	20°					
5/16	18°	20°				
3/8	16°	18°	20°			
7/16	15°	17°	18°			
1/2	13°	15°	17°	20°		
9/16	12°	14°	16°	19°		
5/8	12°	13°	15°	18°	20°	
11/16	11°	13°	14°	17°	19°	
3/4	10°	12°	13°	16°	18°	20°
7/8	9°	11°	12°	15°	17°	18°

*Either or both plates of test specimen.

TABLE 5.12.1.7c

Fillet Weld T-Bend Angles

Minimum Acceptable Angles of Bend for T-Bend Tests of Fillet Welds Made with E-80 Grade Electrodes on steels with minimum specified yields of 60 ksi or greater*.

Stem Thickness	Fillet Weld Size					
	1/4	5/16	3/8	1/2	5/8	3/4
1/4	16°					
5/16	14°	16°				
3/8	13°	15°	16°			
7/16	12°	14°	15°			
1/2	11°	13°	14°	16°		
9/16	10°	12°	13°	15°		
5/8	10°	11°	12°	14°	16°	
11/16	9°	10°	12°	14°	15°	
3/4	8°	10°	11°	13°	15°	16°
7/8	7°	9°	10°	12°	14°	15°

*Either or both plates of test specimen.

6. INSPECTION

PART A - GENERAL REQUIREMENTS

6.1 General. For FCMs, there are requirements which supersede those presently specified in the AWS/AASHTO Structural Welding Code Section 6. (The present paragraphs 6.1.1, 6.1.2 and 6.1.3 shall be deleted and replaced with the following:)

6.1.1 Quality Control (QC) is the responsibility of the Contractor; Quality Assurance (QA) is the prerogative of the Engineer. In FCMs, QC may be randomly verified by QA performing actual nondestructive testing of welds previously found acceptable by QC.

6.1.1.1 If a weld is found to contain rejectable planar-type indications in verification sampling, the two (2) consecutive welds of the same type preceding the defective weld, shall be verified by QA. If two consecutive welds are found by QA to contain rejectable planar-type indications, four (4) consecutive welds of the same type preceding the defective welds shall be verified by QA; etc.

6.1.1.2 In the event that QA inspection, as directed by the Engineer, discloses defective welds, the repair and reinspection of the defective welds shall be performed by the Contractor at his expense.

6.1.2 The Welding Inspector(s) performing QC for FCMs shall be qualified under provisions of the American Welding Society (AWS) Qualification and Certification Program, or other demonstration of competance acceptable to the Engineer.

6.1.3 Personnel performing nondestructive testing of FCMs in both QC and QA shall be qualified as NDT Level-II technicians under ASNT Recommended Practice SNT-TC-1A.

6.1.3.1 The Engineer shall have the option to verify the qualifications of NDT Level-II technicians by performance testing. The Engineer will make the final determination as to the acceptability of all welds.

6.1.3.2 Groove welds in FCMs shall be tested by both radiographic (RT) and Ultrasonic (UT) methods, as well as any other method specified on the drawings per 1.3.4.

6.1.3.3 Ultrasonic testing (UT) of FCMs shall be done by an ASNT Level-II person under the supervision of an ASNT-Certified Level-III person.

6.1.4 The Inspector* designated by the Engineer shall be notified at least eight (8) hours in advance, of the start of any welding operations.

6.1.5 The QC Welding Inspector shall be furnished with complete, revised as necessary, detail drawings which (1) designate which members are fracture critical and (2) specify which welds are to receive nondestructive inspection and by what method.

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*The Inspector is the duly designated person who acts for and in behalf of the Engineer on all inspection and quality matters within the scope of this code.

6.1.6 The QC Welding Inspector shall ascertain that all fabrication by welding is performed in accordance with the requirements of this Code.

6.2 Inspection of Materials. (This paragraph shall be deleted and replaced with the following:)

6.2.1 The QC Welding Inspector shall verify that only materials conforming to the requirements of this Code are used.

6.2.1.1 Plate materials which are to be used in FCMs shall be color coded to identify those plates which have been tested for fracture toughness.

6.2.1.2 The location of each plate of each heat of steel shall be recorded by heat number on a copy of the shop drawings and shall be made a permanent part of the Contract records.

6.2.1.3 The steel producer's certified mill test reports shall be examined for conformance to this Code and the findings shall be reported in writing to the Engineer.

6.2.1.4 The welding consumables shall be examined for conformance to this Code and the findings shall be reported in writing to the Engineer.

6.3 Inspection of Welding-Procedure Qualification and Equipment. (The present paragraphs 6.3.1 and 6.3.2 shall be deleted and replaced with the following:)

6.3.1 The QC Welding Inspector shall make certain that the variables under AWS D1.1 paragraph 5.5, as amended, are accurately recorded in the course of weld-procedure qualification and included in the weld-procedure specification.

6.3.1.1 The QC Welding Inspector shall verify that amperage and voltage are accurately metered in making the weld-procedure-qualification test plates.

6.3.2 The QA Welding Inspector designated by the Engineer shall be present when weld-procedure-qualification test plates are prepared by the Contractor. The Contractor shall notify the Engineer at least 24 hours in advance of preparing his weld-procedure-qualification test plates.

6.4 Inspection of Welder, Welding Operator and Tacker Qualifications.

6.4.3 (The present paragraph 6.4.3 shall be deleted and replaced with the following:)

6.4.3 The Inspector will require requalification of any welder, welding operator or tacker who for 90 days or longer has not used the process and/or position for which he had been previously qualified.

6.5 Inspection of Work and Records.

(The following paragraph shall be added under subsection 6.5:)

Except as revised below, AWS D1.1 paragraphs 6.5.1 through 6.5.7 shall refer to the "QC Welding Inspector" in lieu of "the Inspector" (see 6.1.1).

6.5.2 (The present paragraph 6.5.2 shall be deleted and replaced with the following:)

6.5.2 The QC Welding Inspector shall make certain that only welding procedures meeting the provisions of 5.1 and 5.2, as amended, are employed, and that the limitations on essential variables of 5.5, as amended, are strictly adhered to in production welding.

6.5.2.1 The welding-procedure specifications applicable to each welding operation shall be attached to the power source for each welding operation.

6.5.5 (The present paragraph 6.5.5 shall be deleted and replaced with the following:)

6.5.5 The QC Welding Inspector shall examine the work to make certain that it meets the requirements of Section 3. Size and contour of welds shall be measured with suitable gages.

6.5.7 (The following shall be added as a 2nd paragraph to the present paragraph 6.5.7:)

The QC Welding Inspector shall keep a record of the processes and positions of welding used by each welder, welding operator and tacker (see 6.4.3, as amended)

6.6 Obligations of the Contractor.

6.6.1 (The present paragraph 6.6.1 shall be deleted and replaced with the following:)

6.6.1 It shall be the Contractor's responsibility to comply with all requests of the QA Welding Inspector to correct improper workmanship and to remove and replace or correct as instructed, all welds found defective or deficient by visual inspection and/or by nondestructive testing as required by the designer (1.3.4). The Contractor shall be responsible for Quality Control (6.1.1) and therefore, shall be responsible for both visual examination and nondestructive testing as specified by the designer (1.3.4), and for corrections thereby indicated.

6.6.3 (The present paragraph 6.6.3 shall be deleted.)

6.6.4 (The present paragraph 6.6.4 shall be deleted and replaced with the following:)

6.6.4 It shall be the Contractor's responsibility to insure that all specified welds (1.3.4) meet the following quality requirements:

6.6.4.1 Visual inspection. A weld shall be acceptable by visual inspection if it shows that:

(1) The weld has no cracks.

(2) There is no evidence of lack of fusion between weld and base metal.

(3) All craters are filled to the full cross section of the weld.

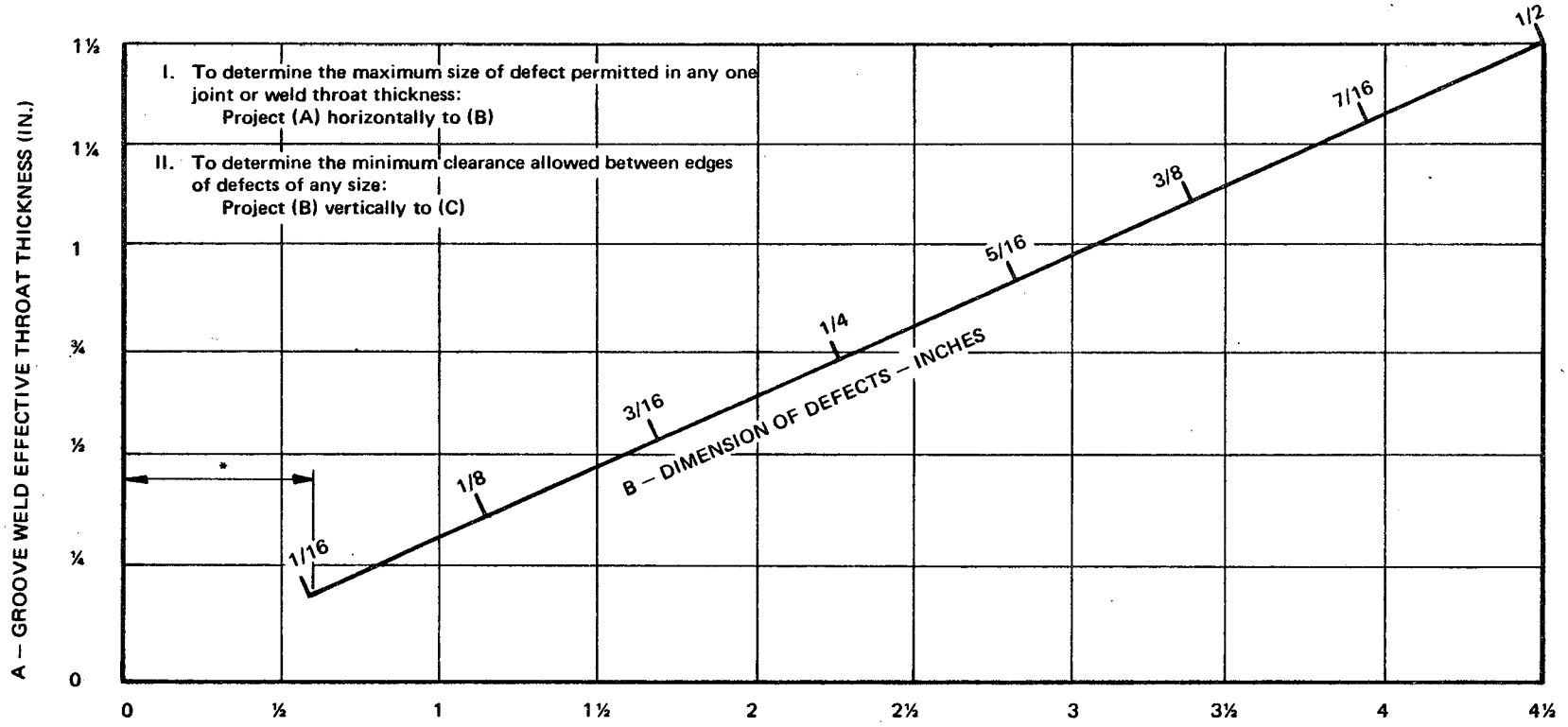
(4) Weld profiles are in accordance with 3.6.

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

(6) Fillet welds in any single continuous weld will be permitted to underrun the nominal fillet size required by 1/16 inch (1.6 mm) 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, or to the depth of the web, whichever is the greater.

(7) Complete-penetration groove-weld butt-, T- and corner-joints perpendicular to the applied stress shall have no piping porosity. For all other groove welds, the frequency of piping porosity shall not exceed the limits specified for fillet welds in 6.6.4.1(5).

(8) When piping porosity 3/32 inch or larger in diameter extends to the surface at intervals of 12 inches or less over a distance of four feet, or when the condition of electrodes, flux, or base metal, or the presence of weld cracking indicates a possible problem with piping porosity, a visual subsurface inspection shall be made 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 one-half (1/2) the design throat. When



*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.

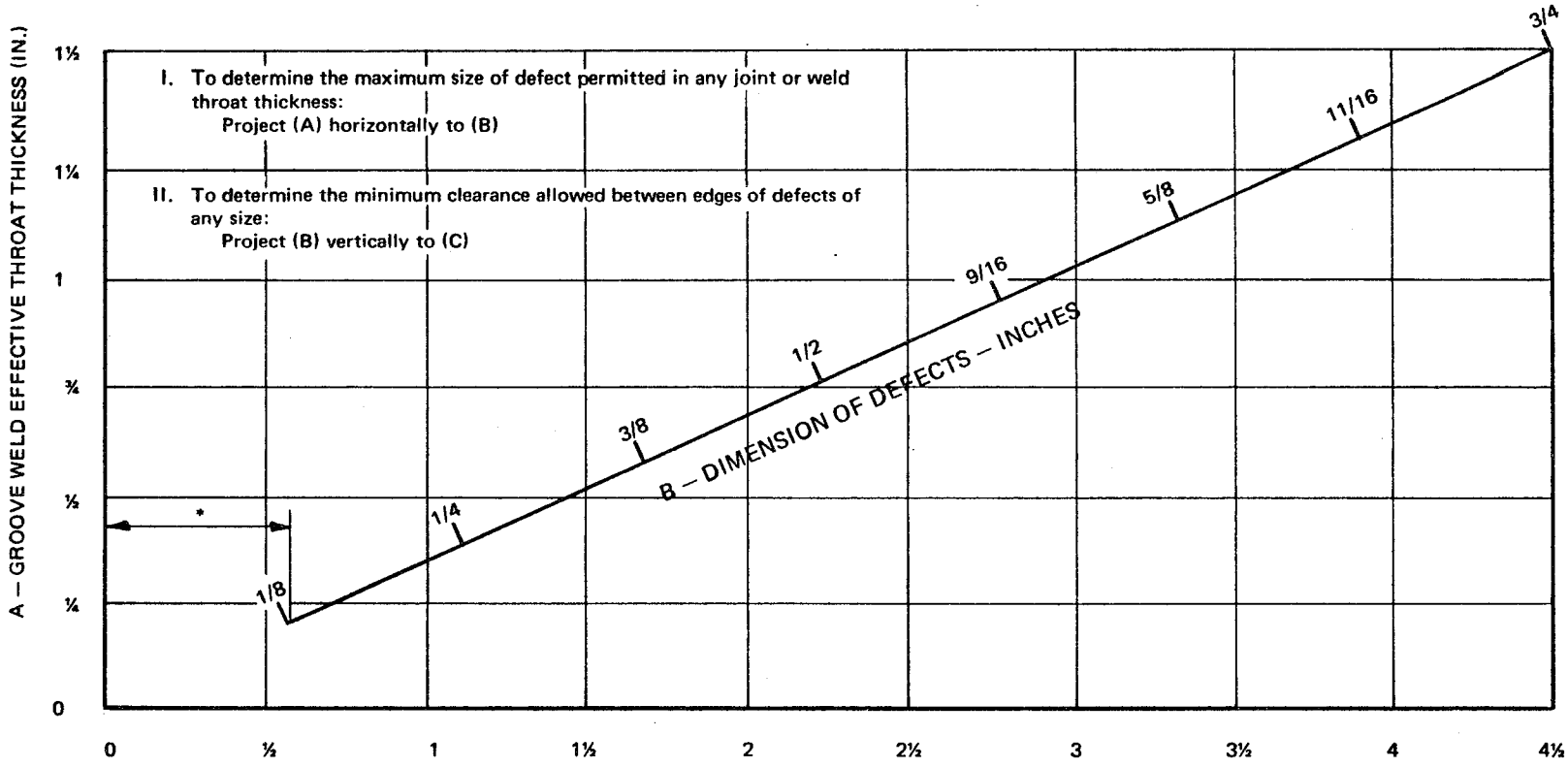
Fig. 6.6.4.2(1) – **Weld Quality Requirements for Defects Occurring in Tension Welds–Bridges (Limitations of Porosity and Fusion-Type Defects)**

viewed at the midthroat 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.

6.6.4.2 Nondestructive inspection (other than ultrasonic testing). Welds that are subject to nondestructive testing, shall have no cracks, no incomplete fusion, not less than the specified penetration, and no other discontinuities exceeding the following limits:

(1) For welds subject to tensile stress under any condition of loading, the greatest dimension of any porosity or fusion-type discontinuity determined by non-destructive inspection that is 1/16 inch or larger in greatest dimension shall not exceed the size, B, indicated in Figure 6.6.4.2(1) for the effective throat 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 the minimum C-clearance allowed, indicated by Figure 6.6.4.2(1) for the size of defect under examination.

(2) For compression and shear welds, the greatest dimension of any porosity or fusion-type discontinuity determined by non-destructive inspection that is 1/8 inch or larger in greatest dimension shall not exceed the size, B, indicated in Figure 6.6.4.2(2) for the effective throat 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



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 ¼ 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. 6.6.4.2(2) – **Weld Quality Requirements for Defects Occurring in Compression Welds—Bridges (Limitations of Porosite and Fusion-Type Defects)**

intersecting weld shall not be less than the minimum C-clearance allowed, indicated by Figure 6.6.4.2(2) for the size of defect under examination.

(3) Independent of the requirements of 6.6.4.2(1) and (2), for those defects whose greatest dimension is less than 1/16 inch in tension or 1/8 inch in compression or shear, the sum of their greatest dimensions shall not exceed 3/8 inch in any linear inch of weld.

(4) The limitations given by Figures 6.6.4.2(1) and (2) for 1-1/2 inch effective weld throat shall apply to all joints or effective weld throats of greater thickness.

6.6.4.3 Ultrasonic inspection. Each weld discontinuity found by ultrasonic testing shall be accepted or rejected on the basis of its defect rating and its length and location in accordance with Table 6.6.4.3.

6.7 Nondestructive Testing.

(The present paragraphs 6.7.1 through 6.7.7, inclusive, shall be deleted and AASHTO Welding Specifications-1977 paragraphs 6.7.8, 6.7.9 and 6.7.10 shall be deleted.)

TABLE 6.6.4.3-ULTRASONIC ACCEPTANCE CRITERIA

MINIMUM ACCEPTANCE LEVELS (DECIBELS)

REFLECTOR SEVERITY	WELD THICKNESS (in.) AND TRANSDUCER ANGLE							
	5/16 to 3/4	>3/4 to 1-1/2	1-1/2 to 2-1/2			2-1/2 to 3		
	70°	70°	70°	60°	45°	70°	60°	45°
Strong Reflectors	+14	+ 9	+ 6	+ 9	+11	+ 4	+ 7	+ 9
Moderate Reflectors	+15	+10	+ 8	+11	+13	+ 6	+ 9	+11
Weak Reflectors	+16	+11	+10	+13	+15	+10	+13	+15

NOTES:

(1) Strong Reflectors: Any discontinuity, REGARDLESS OF LENGTH, having a more serious rating (smaller number) than this level shall be rejected.

Moderate Reflectors: Any discontinuity longer than 3/4 in. (19 mm) having a more serious rating (smaller number) than this level shall be rejected.

Weak Reflectors: Any discontinuity longer than 2 in. (51 mm) having a more serious rating (smaller number) than this level shall be rejected.

(2) Discontinuities which have a more serious rating than those of "Weak 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.

(3) Discontinuities which have a more serious rating than those of "Weak 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.

(4) Discontinuities detected at 'Scanning Levels' in the root-land areas of complete joint penetration double-V-, double-J-, double-U- and double-bevel-groove welds shall be evaluated at an acceptance level 4db* more sensitive than prescribed in this table when such welds are designated on design drawings as 'tension welds'.

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*i.e., add +4 db to the number in the table.

PART B

RADIOGRAPHIC TESTING OF GROOVE WELDS

6.8 General.

(The present paragraphs 6.8.1 and 6.8.2 shall be deleted and replaced as follows:)

6.8.1 The procedures and standards herein described are specifically for radiographic examination of groove welds in butt joints by X-ray or gamma-ray sources. The methodology shall conform to ASTM E94 "Standard Recommended Practice for Radiographic Testing" and ASTM E142 "Standard Method for Controlling Quality of Radiographic Testing, except as amended herein.

6.8.2 Any variation from the provisions of these specifications must have the prior approval of the Engineer and confirmed in writing. All radiographic inspection performed in Quality Control and/or in Quality Assurance shall conform to the requirements of this Code.

6.9 Extent of Testing.

(The present paragraphs 6.9.1, 6.9.2 and 6.9.3 shall be deleted and replaced with the following:)

6.9.1 All groove-weld butt joints in FCMs as defined in 1.2.1 shall be radiographed including attachment butt joints contiguous to the tension component of an FCM.

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

6.9.3 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 affects of "Live Loads".

6.9.4 Stringer and girder 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. When a web joint is subject to reversal of stress, the entire web splice shall be radiographed.

6.9.5 Repairs. "Spot" inspection and "spot" radiography shall not be used except for the examination of localized repairs in welds previously rejected by visual or nondestructive 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.

6.9.6 Radiographic Inspection of welds subject to shear or compression.

Any groove weld in a butt joint (excludes welds detailed on the plans as partial penetration) may be subject to radiographic inspection regardless of stress if required by the Contract Documents or ordered by the Inspector.

The Inspector shall, at the completion of welding, (generally the next working day) mark, at random, 10% of the compression and shear welds for radiographic testing. A sufficient number of compression and shear welds shall be radiographed to represent 10 percent of the length of each weld joint or 10 percent of the compression or shear joints in each erection piece or of the total erection pieces in each span.

If more than 10 percent of the compression or shear welds are found to be defective, all such welds in that member or all welds in that span not previously radiographed shall be radiographed. One hundred percent radiographic inspection shall continue until the rejection rate falls to 10 percent or less at which time the testing shall revert to the sampling level specified above.

If defects are found in an 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.

TABLE 6.10.1

THICKNESS, PENETRAMETER DESIGNATIONS AND ESSENTIAL HOLES
To Produce Required Equivalent Penetrameter Sensitivity

Material Thickness Range, In.	Penetrameter Designation	Thickness of Penetrameter, In.	Essential* Hole
Up to 1/4, incl	5	0.005	4T
Over 1/4 thru 3/8	7	0.007	4T
Over 3/8 thru 1/2	10	0.010	4T
Over 1/2 thru 5/8	12	0.0125	4T
Over 5/8 thru 3/4	15	0.015	4T
Over 3/4 thru 7/8	17	0.0175	4T
Over 7/8 thru 1	20	0.020	2T
Over 1 thru 1-1/4	25	0.025	2T
Over 1-1/4 thru 1-1/2	30	0.030	2T
Over 1-1/2 thru 2	35	0.035	2T
Over 2 thru 2-1/2	40	0.040	2T
Over 2-1/2 thru 3	45	0.045	2T

*NOTE:

Equivalent Penetrameter Sensitivity is defined as "...that thickness of penetrameter, expressed as a percentage of the part thickness, in which a 2T hole would be visible under the same radiographic conditions." Table 6.10.1 is identical to the requirements of the ASME Boiler and Pressure Vessel Code. Penetrameters 5, 7, 10, 12, 15 and 17 produce 2.8% penetrameter sensitivity or less. Radiographic inspection of steel 7/8 inch thick or less cannot always be relied upon to delineate discontinuities having a thickness equal to 2.0% of the thickness of the part.

6.10 Radiographic Procedure.

(The present paragraphs 6.10.1 through 6.10.7 shall be deleted and replaced as follows:)

6.10.1 Radiographs shall be made using a single source of either X or gamma radiation. The minimum radiographic sensitivity shall be 2-2T or 2-4T depending on thickness as described in Table 6.10.1. The equivalent penetrameter sensitivity for these levels of inspection is 2.0 and 2.8 percent, respectively.

Radiographic technique and equipment shall provide sufficient sensitivity to clearly delineate the required penetrameters and the essential holes as described in the specification. The density difference between the image of the holes and the penetrameter image shall be the same as that between the edge of the penetrameter and the adjacent film area. Identifying numbers and letters shall show clearly on the radiographs.

6.10.2 All butt welded joints subject to radiographic inspection shall be ground smooth before being radiographed. Welds in plate 3/4-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:

PLATE (in.) THICKNESS	THICKNESS of REINFORCEMENT (in.) each side	Total
over 3/4 to 1	3/64	3/32
over 1 to 2	1/16	1/8
over 2 to 3	3/32	3/16

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 shall be permitted on the side of a joint that is a faying surface, contact surface or exposed surface of fascia girders.

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

6.10.3 Preparation for exposure. All film cassettes shall be loaded with two fine grain films of the same specification. Appropriate lead screens shall be used. Fluorescent screens will not be permitted. A center-lead-foil intensifying screen is recommended when its use reduces the exposure time. 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 centered on a line directly above and perpendicular to the length of weld being 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:

Maximum Thickness of Weld Under Examination (T)	Minimum Source-to-Subject Distance
1/4" to 2"	24"
over 2" to 2 1/2"	18"
over 2 1/2 "	7T

6.10.4 Radiographic source. X-ray units 600 kvp maximum 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.

6.10.5 Penetrameters. At least two penetrameters shall show clearly on each radiograph. The penetrameters shall be placed on the source side of the joint being radiographed.

When a transition in thickness occurs at a welded joint, each film shall clearly show two penetrameters on the thinner plate and one penetrameter on the thicker plate. When it is necessary to radiograph a joint representing a major change in thickness, the penetrameter representing the maximum plate thickness may be placed on the sloping surface of the base metal outside the weld zone as shown in Figure 6.10.5.a.

Penetrameters shall be placed parallel to the weld joint with the holes at the outer end as shown in Figure 6.10.5.a. Penetrameters shall be of the thickness or thicknesses required by Table 6.10.1

Penetrameters shall be manufactured from steel, preferably stainless steel and conform to the dimensions shown in Figure 6.10.5.b. For more detailed information on the manufacture of penetrameters see ASTM E142.

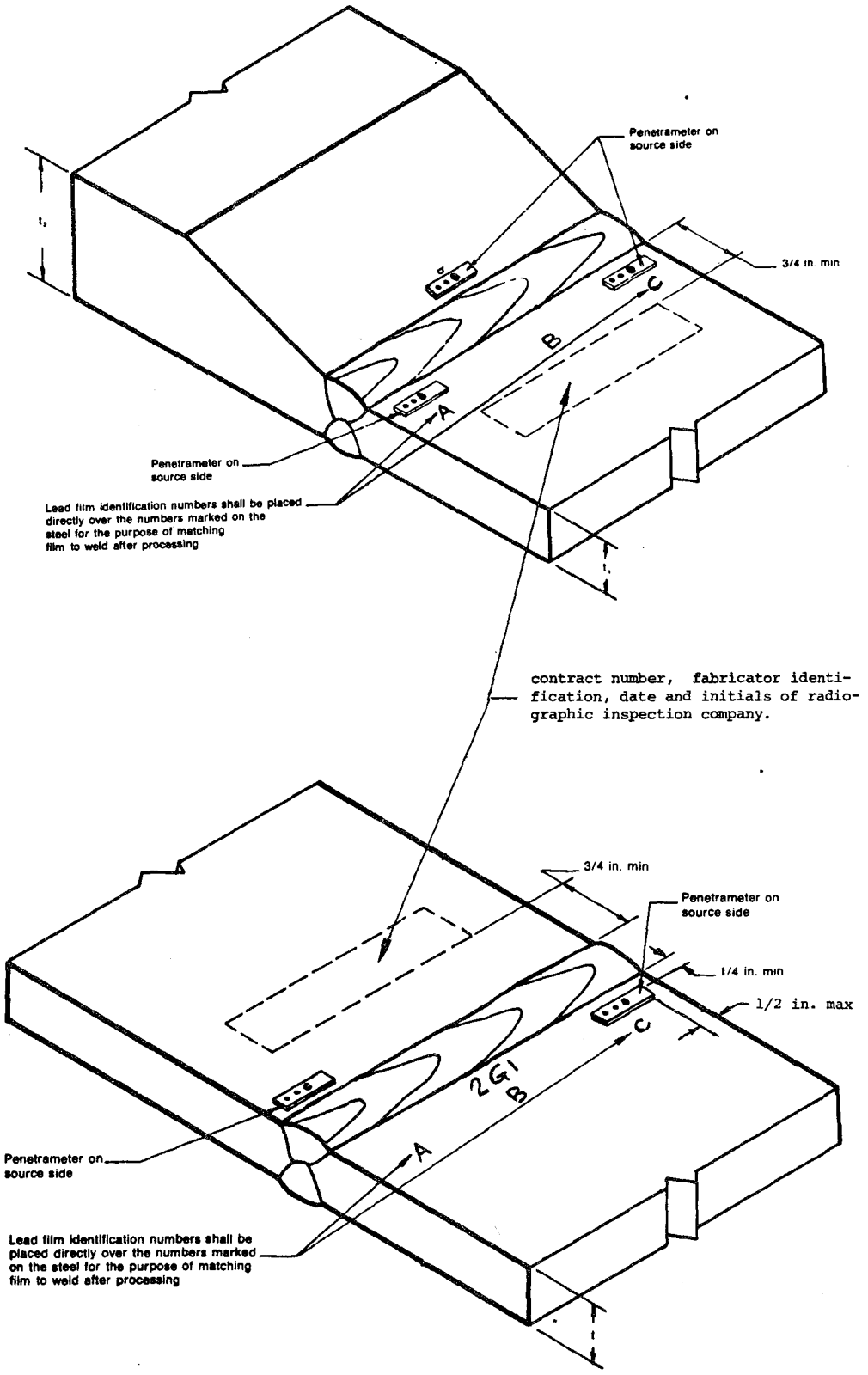
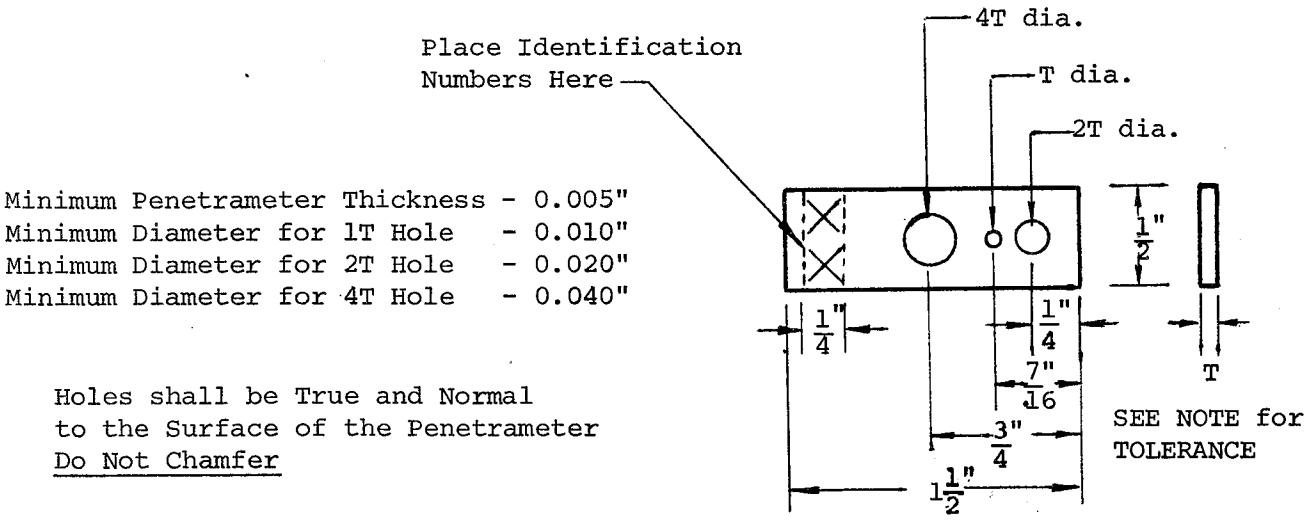


FIG. 6.10.5.a - RADIOGRAPH IDENTIFICATION

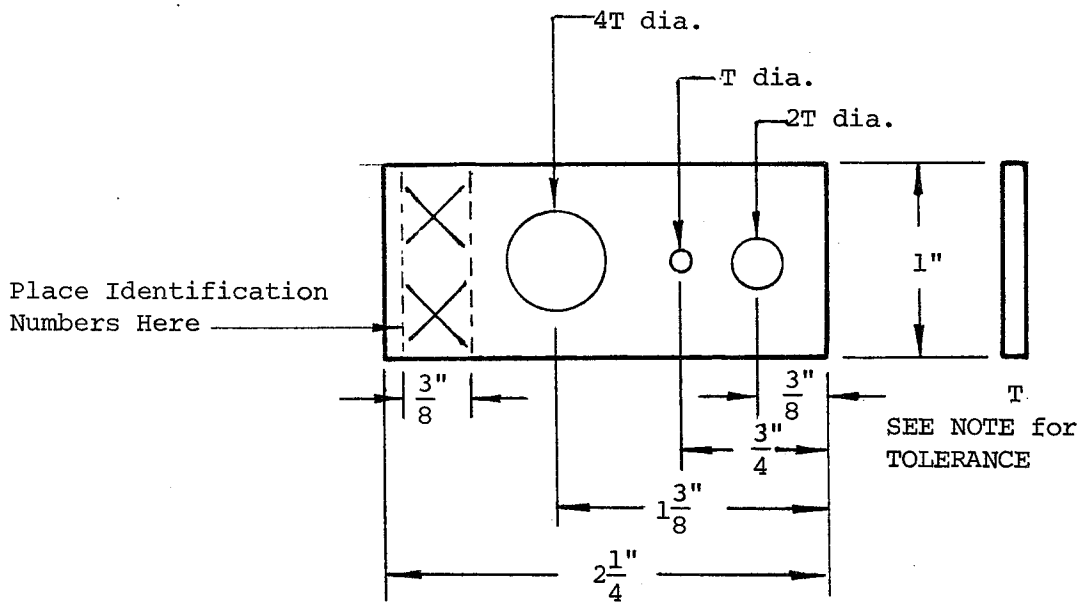


Minimum Penetrameter Thickness - 0.005"
Minimum Diameter for 1T Hole - 0.010"
Minimum Diameter for 2T Hole - 0.020"
Minimum Diameter for 4T Hole - 0.040"

Holes shall be True and Normal
to the Surface of the Penetrameter
Do Not Chamfer

Design for Penetrameter Thickness from 0.005 in. and including 0.050 in.
From 0.005 in. through 0.012 in. Made in 0.001 in. Increments.
From 0.012 in. through 0.020 in. Made in 0.0025 in. Increments.
From 0.020 in. through 0.050 in. Made in 0.005 in. Increments.

Penetrameter thicknesses between the increments indicated are permitted, provided they do not exceed the maximum thickness required.



Design for Penetrameter Thickness from 0.060 in. to and including 0.160 in. Made in 0.010 in. Increments.

NOTE 1: Tolerances on penetrameter thickness and hole diameter shall be ±10 percent or one-half of the thickness increment between penetrameter sizes, whichever is smaller.
NOTE 2: 1 in. = 25.4 mm.

FIG. 6.10.5.b - PENETRAMETER DESIGN

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

Each penetrameter shall be manufactured with three holes, one of which shall be of a diameter equal to twice the penetrameter thickness (2T). 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 penetrameter thickness. Penetrameter Designations 5, 7, 10, 12, 15 and 17 shall contain a 4T hole.

6.10.6 Continuity of inspection. Welded joints shall be radiographed and the film indexed by a method that will provide complete and continuous inspection of the joint within the limits specified. Joint limits shall 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 shall have sufficient length to produce 1/2 inch of "black" (film exposed to direct radiation from the source) beyond any plate edge.

Weld joints longer than 15 inches may be radiographed either by overlapping film cassettes and making a single exposure or by using single film cassettes and making separate exposures. The method used shall provide complete and continuous inspection, produce radiographs of acceptable quality and meet the requirements of Section 6.10.3.

In general, webs and flanges shall be radiographed before the member is assembled. When, because of some unusual situation, it is necessary

to radiograph butt splices in a member already assembled in a T or I configuration, the source shall be on the web side of the flange, and the film shall be placed against the outside flange surface such that both the flange edge and the web-to-flange weld are clearly delineated on film. A similar technique shall be used for radiographing webs of members already assembled.

6.10.7 Film size. When the joint thickness is 3 inches or less, radiographs may be 4 1/2 inches x 17 inches 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 4 1/2 inches x 10 inches. When joint thicknesses are greater than 3 inches, 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.

6.10.8 Film density and quality. All radiographs shall be clean and free of film and processing defects. Film stains, excessive water marks, pressure marks, or artifacts caused by screen scratches, light leaks in cassettes, or other deficiencies in the radiograph that interfere with interpretation shall be cause for rejection of the film. In general, quality of the radiograph will be determined by the quality of the penetrameter images and freedom from film defects. The use of film-side penetrameters shall be cause for rejection of the radiographs.

Radiographs shall have an Hurter and Driffield (H&D) of 1.5 minimum to 4.0 maximum. Densities within the range of 2.5 ot 3.5 are preferred.

When transitions in thickness are radiographed where the ratio of the thicker plate to 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 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.

6.10.9 Equipment for viewing radiographs. All radiographs shall be reviewed on a variable intensity illiminator (viewer) of the spot-review type. The viewer shall incorporate a means for 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.

A suitable variable intensity viewer shall be furnished by the Contractor for the use of the Inspector when reviewing radiographs. The viewer shall be available whenever radiography is being performed and shall remain available for two weeks after radiographic inspection has been completed.

6.10.10 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) 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) Penetrameters

See Figure 6.10.5.a 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 5/16th inch. The Contractor will be permitted to preprint the 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 use of lead numbers.

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.

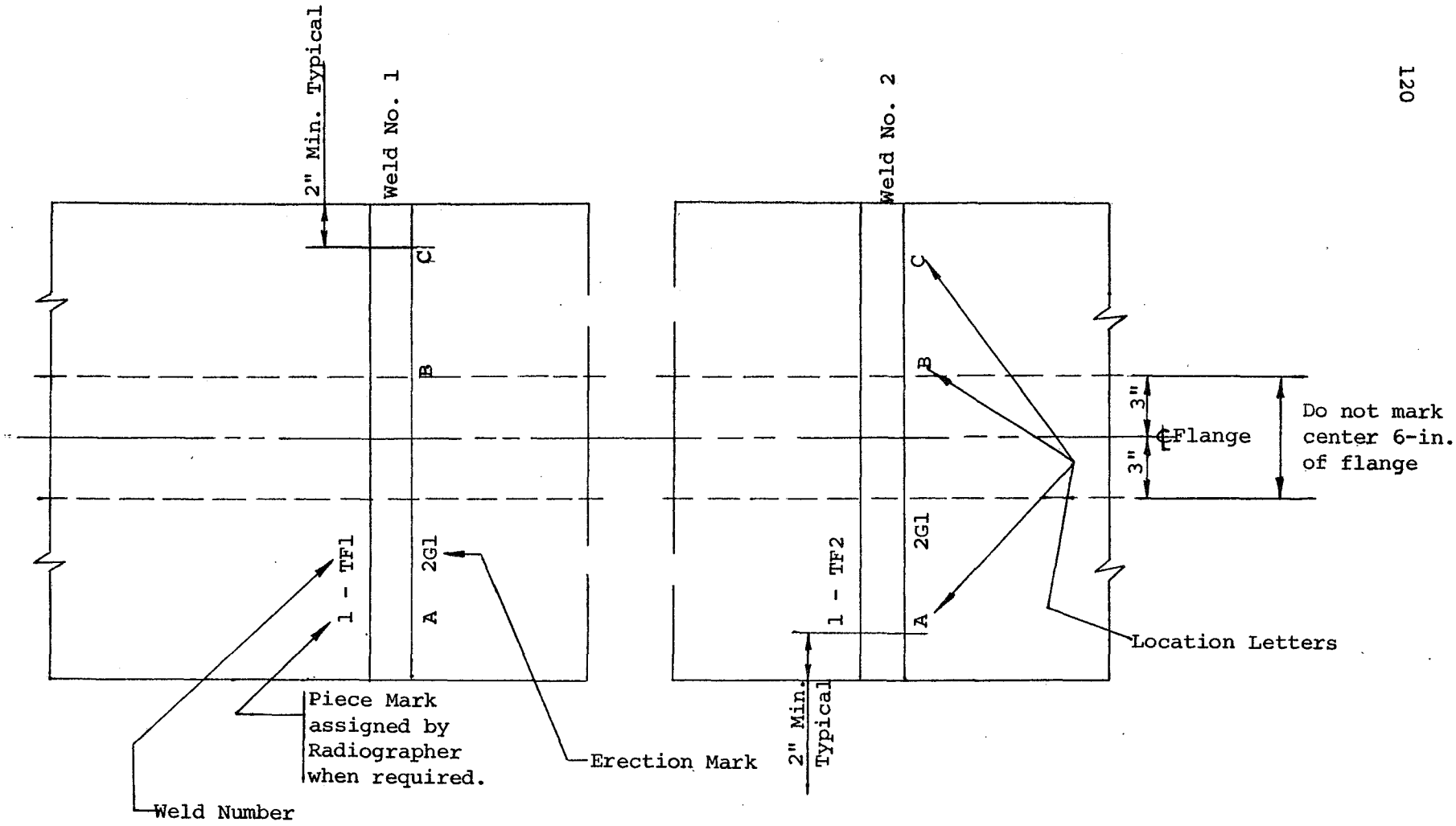


FIG. 6.10.11 - PERMANENT STEEL IDENTIFICATION

6.10.11 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.

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 6.10.11. The RT and the UT "Y" reference marks for each weld joint shall be at the same (left) end of the weld.

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 Figures 6.10.5.a and 6.10.11. Spacing shall be somewhat random. Templates shall not be used. In general, when radiographs are viewed in register, only thos 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 RT.

To insure that the exact location of the center of the weld is not lost during the work, two center-punch marks shall be placed 12 ±1/16 inch from the center of the weld. These marks shall be placed on both sides of the weld with impressions 3 ±1/8 inch from each plate edge.

6.11 Acceptability of Welds.

(The present paragraph 6.11 shall be deleted and replaced as follows:)

6.11.1 Welds subject to radiographic inspections shall have no cracks regardless of the direction of stress. Porosity or fusion-type defects shall be evaluated by the following criteria for tension welds: 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 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 intersection weld shall not be less than C-Minimum Clearance Allowed, indicated in Fig. 6.6.4.2(1) for the size of defect under examination.

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. 6.6.4.2(1) for the effective throat thickness or weld size involved, no repair shall be required.

The limitation given by Fig. 6.6.4.2(1) for a 1 1/2 inch joint or weld throat thickness shall apply to all joints or weld throats of greater thickness.

6.11.1.1 Independent of the requirements specified above, 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.

6.11.2 Compression and shear welds in bridges. The greatest dimension of any porosity and 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. 6.6.4.2.(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 intersection weld shall not be less than C-Minimum Clearance Allowed, indicated by Fig. 6.6.4.2.(2) for the size of defect under examination.

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 Figure 6.6.4.2.(2) for the effective throat thickness or weld size involved, no repairs shall be required.

The limitations given by Figure 6.6.4.2.(2) for 1 1/2-in. joint weld throat thickness shall apply to all joints or weld throats of greater thickness.

6.11.2.1 Independent of the requirements of Fig. 6.6.4.2(2), the sum of the greatest dimensions of porosity and fusion-type defects less than 3/32 inch in greatest dimension shall not exceed 3/8 inch in any linear inch of weld.

6.12 Examination, Reporting and Disposition of Radiographs.

(The present paragraph 6.12.1 through 6.12.3 shall be deleted and replaced with the following:)

6.12.1 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 organization 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 AWS D1.1 Appendix p. 143.

6.12.2 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 penetrameter designations shall be shown adjacent to the joint. The direction of lettering of web welds shall be explained. No films shall be forwarded to the Inspector as accepted that contain any indication that could be interpreted as a rejectible 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 shall be removed before the joint is radiographed.

Duplicate radiographs may be submitted when films with processing marks, artifacts or scratches could be interpreted as containing rejectionable discontinuities.

6.12.3 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.

6.12.4 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 Engineer. 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 Engineer not later than two business days following the acceptance of the 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.

PART C

ULTRASONIC TESTING OF GROOVE WELDS

6.13 General.

6.13.1 (The present paragraph 6.13.1 shall be deleted and replaced with the following:)

6.13.1 The precedures and standards set forth in this section shall govern the ultrasonic testing (UT) of groove welds between the thicknesses of 5/16 and 3 inches, inclusive.

6.13.3 (The present paragraph shall be deleted.)

6.14 Extent of Testing.

(The present paragraphs 6.14.1, 6.14.2 and 6.14.3 shall be deleted and replaced with the following:)

6.14.1 In FCMs all groove welds shall be ground flush and UT tested, including any attachment groove-weld butt-, T- and corner-joints contiguous to the tension component of an FCM.

All groove-weld procedure-qualification test plates shall be ground flush and UT tested.

6.14.2 In groove-weld butt-, T- and corner-joints, the complete length of the weld in each designated joint (see 1.3.4) shall be tested.

Extraordinary attention shall be given to the ends of welds at locations where run-off plates were attached, and at the intersection of welds.

6.15 Ultrasonic Equipment.

6.15.3 (The present paragraph 6.15.3 shall be deleted and replaced with the following:)

6.15.3 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.

6.18 Calibration for Testing.

6.18.1 (The present paragraph 6.18.1 shall be deleted and replaced with the following:)

6.18.1 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.

Ultrasonic 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 Engineer.

Clipping control, suppression control, reject control or any other control whose function is to filter the CRT presentation shall not be used without the prior approval of the Engineer. When the use of these controls is approved, it shall be clearly noted in the ultrasonic test report. These controls shall not be changed following calibration or during testing.

6.18.2.2 (The present paragraph 6.18.2.2 shall be deleted and replaced with the following:)

6.18.2.2 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 40 and 70 percent of full screen height.

6.18.3.1 (A second paragraph shall be added to the present paragraph 6.18.3.1 as follows:)

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 5- or 10-inch scale.

6.19 Testing Procedures.

6.19.2 (The present paragraphs 6.19.2, 6.19.3 and 6.19.4 shall be deleted and replaced with the following:)

6.19.2 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.

6.19.3 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 Engineer.

6.19.4 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 6.15.6, and calibrated in accordance with 6.18.2.

6.19.4.1 If any area of base metal exhibits loss of back reflection considered rejectable by the "Amplitude" method of lamination testing as described in 6.19.4.4, 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.

Using the scanning patterns in Figure 6.19.5.1, examine the inaccessible part of the weld by testing from both faces in order to attain full weld evaluation.

6.19.4.2 Laminations adjacent to tension groove welds. If laminar defects are found by visual or nondestructive tests adjacent to tension groove welds, before welding, the base metal shall be tested for soundness in accordance with the following procedure:

The end 6 inches of plate or shape adjacent to a 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 6.18.2 using a straight beam search unit conforming to the requirements of 6.15.6. The test pattern shall overlap to insure 100% inspection. The 6 inches of plate shall be tested by the "Total Loss of Back Reflection Method" as described in 6.19.4.3. Any lamination found rejectable by this test shall cause 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 immediately adjacent to the groove-weld edge preparation shall be retested using the "Amplitude Method" as described in 6.19.4.4. 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 3.2.3 reveals defects in excess of the limits specified by 3.2.3.3.4.

6.19.4.3 Total loss of back reflection method. The instrument shall be adjusted as described in 6.18.2.1 and 6.18.2.2. 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 midthickness 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.

6.19.4.4 Amplitude method. The horizontal sweep shall be adjusted as described in 6.18.2.1. The sensitivity shall be adjusted as described in 6.18.2.2 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.

6.19.5.1 (The present paragraph 6.19.5.1 shall be deleted and replaced with the following:)

6.19.5.1 Scanning patterns. All welds shall be scanned from both sides on the same face where mechanically possible using the scanning movements and patterns of Figure 6.19.5.1, executed on a systematic, preplanned basis.

6.19.5.6 (The present paragraphs 6.19.5.6 and 6.19.5.7 shall be deleted and replaced with the following:)

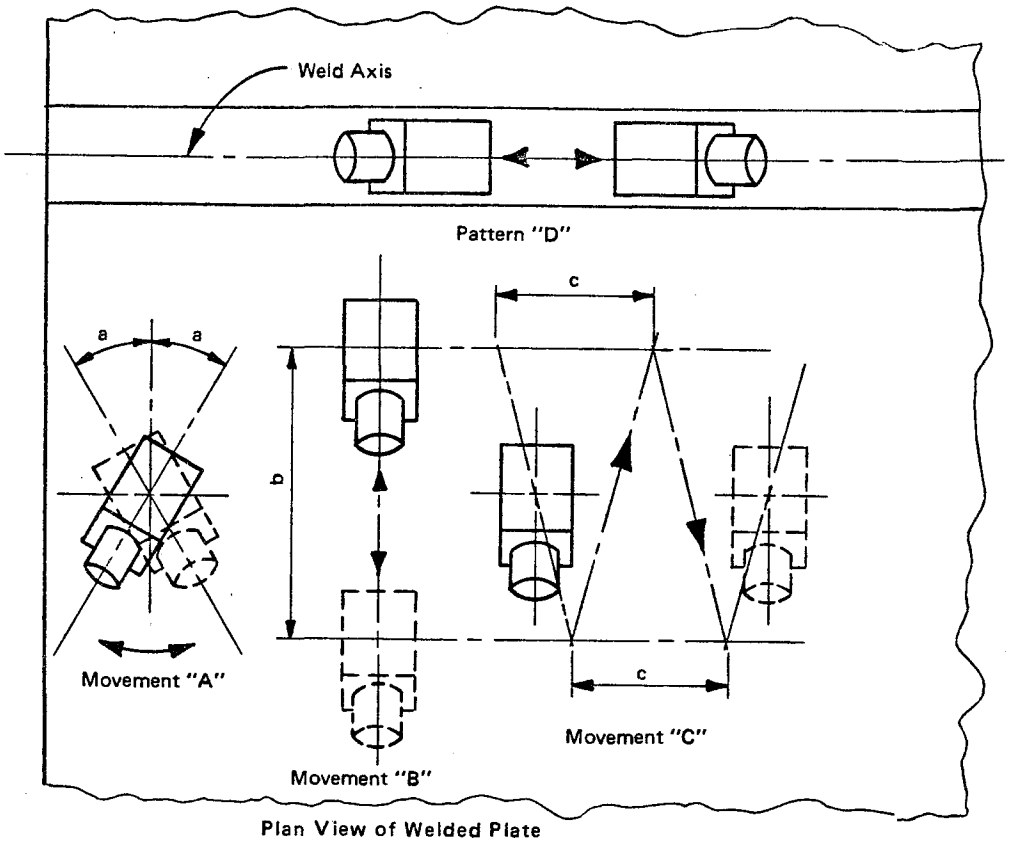
6.19.5.6 Defect length. The length of a discontinuity as entered under "Defect Length" on the test report, Figure 6.20.1, shall be determined by locating the points at each end at which the indication amplitude drops or rises 6 decibels, and measuring between the points from the center of the transducer 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.

6.19.5.7 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 6.6.4.3.

6.20 Preparation and Disposition of Reports.

(The present paragraphs 6.20.1, 6.20.2 and 6.20.3 shall be deleted and replaced with the following:)

FIGURE 6.19.5.1 - SCANNING PATTERNS/MOVEMENTS



NOTES:

(1) for scanning-movement "A", rotation angle "a" is 10 degrees

(2) for scanning-movement "B" the scanning distance "b" shall be such that the full section of the weld being tested is covered.

(3) for scanning-movement "C", the progression distance "c" shall be approximately one-half the transducer width.

(4) scanning-movements "A", "B" and "C" shall be combined into one scanning pattern, and shall be executed from both sides of the weld axis where mechanically possible.

(5) scanning-pattern "D" shall be combined with scanning-movement "A" and the weld traversed in both weld directions.

(6) testing patterns are all symmetrical about the weld axis with the exception of Pattern "D" which is conducted directly over the weld axis.

(7) for FCMs all of the above scanning-patterns and movements shall be executed on each groove-weld butt-, T- and corner-joint.

6.20.1 An ultrasonic test report which clearly identifies the weld and the area of inspection shall be completed by the ultrasonic technician at the time of inspection. The test report, AWS D1.1 page 142 shall be supplemented by dimensioned sketches, as necessary to adequately describe the defect as to position and size as required under 3.7.5 and 3.7.6.

The ultrasonic test report shall include the Contract Number, the date the inspection was made, and the name of the inspector. The test report shall not only record all rejectable discontinuities but also all other indications with defect ratings within 5 db of being rejectable. The latter shall be fully recorded as to indication rating, size and position.

Repaired welds shall be retested ultrasonically and recorded on a continuation of the original report form.

6.20.2 Prior to acceptance of a weld subject to ultrasonic inspection by the Contractor, all of the Report Forms pertaining to the weld, including any that show unacceptable quality prior to repair, shall be submitted to the Inspector.

6.20.3 A full set of completed ultrasonic test reports and dimensioned sketches for all welds tested, including any that show unacceptable quality prior to repair, shall be delivered to the Engineer upon completion of the work. The Contractor's obligation to retain ultrasonic reports shall cease upon delivery of this full set to the Engineer.

6.21. Calibration of Ultrasonic Equipment.

6.21.1.2(2) (The present paragraph 6.21.1.2(2) shall be deleted and replaced with the following:)

6.21.1.2(2) Adjust gain until maximized indication from the first back reflection attains 40 to 70 percent screen height.

6.21.2.4(7) (The present paragraph 6.21.2.4(7) shall be deleted and replaced with the following:)

6.21.2.4(7) This decibel reading is used as the "Reference-Level b" reading in the UT Testing Report, AWS D1.1 page 142. Differences between sensitivity measurements made on the DC or DSC blocks and the IIW block shall be accounted for when determining "Reference-Level b".

6.21.2.5(2) (The present paragtaph 6.21.2.5(2) shall be deleted and replaced with the following:)

6.21.2.5(2) Transducer and instrument shall resolve the three test holes.

6.22 Scanning Patterns.

(The present paragraphs 6.21.1 through 6.21.3 shall be deleted; see 6.19.5.1.)

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