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An American National Standard

Structural Welding Code—Seismic Supplement

American Welding Society

Approved American National Standard
ANSI

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An American National Standard

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Structural Welding Code—Seismic Supplement

2nd Edition

Supersedes AWS D1.8/D1.8M:2005

Prepared by the
American Welding Society (AWS) D1 Committee on Structural Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This code supplements the requirements of AWS D1.1/D1.1M, *Structural Welding Code—Steel*. This code is intended to be applicable to welded joints in Seismic Force Resisting Systems designed in accordance with the AISC Seismic Provisions. Clauses 1–7 constitute a body of rules for the regulation of welding in Seismic Force Resisting Systems. There are seven mandatory annexes in this code. A commentary of the code is included with the document.

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Foreword

This foreword is not part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, but is included for informational purposes only.

This is the second edition of the AWS D1.8/D1.8M, *Structural Welding Code—Seismic Supplement.*

Editorial and technical revisions from the previous edition are indicated by underlining text. Changes in tables and figures have a single, vertical line in the margin. The following is a list of significant revisions in the 2009 edition:

(1) Subclause 1.3—Code limitations have been revised to apply to structures with minimum specified strength of 55 ksi [380 MPa].

(2) Changed Seismic Load Resisting System (SLRS) to Seismic Force Resisting System (SFRS) to be consistent with terminology as revised in AISC Seismic Provisions.

(3) Subclause 4.2—For Welded Connection Details, a new subclause on Transition Thickness and Width for butt joints has been added.

(4) Figures 4.1 and 4.2—New figures added to illustrate detail of the transition of butt joints for unequal thicknesses.

(5) Subclause 6.1.1—New section added to specify acceptability of prequalified and qualified WPS in accordance with the D1.1 code.

(6) Subclause 6.1.2—Clarified the requirement that WPS for Demand Critical Welds utilize variables that produce heat inputs within the filler metal tested heat input envelope.

(7) Subclause 6.1.3—New section adding provisions for the use of filler metals tested as described for the "-D" designator in AWS A5.20/A5.20M:2005 for Demand Critical Welds.

(8) Subclause 6.3.2—Clarified and corrected diffusible hydrogen requirements for filler metals.

(9) Subclause 6.3.5—Restricted exemptions from heat input envelope testing to LAST equal to or greater than 50°F [+10°C].

(10) Subclause 6.3.5(4)—Added an exemption from heat input envelope testing for low alloy FCAW, GMAW, and SAW electrodes that are optionally tested by the filler metal manufacturer in accordance with AWS A5.17 Clause 17 for the "-D" designator.

(11) Subclause 6.3.6—Modified to disallow exemptions from heat input envelope and classification lot testing when LAST is less than +50°F [+10°C].

(12) Subclause 6.3.8—Clarified lot control provisions for filler metals were required only for Demand Critical welds and that lot testing included both classification and heat input envelope tests.

(13) Subclause 6.13—Revised welder identification requirements to permit methods other than the use of stamps or marks on the piece.

(14) Table 6.1—Clarified so that filler metals with 20 ft·lbf [27 J] min. tested at a temperature lower than 0°F [–18°C] meet CVN Toughness Property.

(15) Table 6.2—Clarified requirement for LAST less than +50°F [+10°C] and to permit CVN tests lower than the specified temperature.

(16) Table 6.3—New table added to illustrate requirements for testing diffusible hydrogen of filler metals.

(17) Figure 6.4(B)—Revised to address weld tab removal.

(18) Subclause 6.12—Content from previous edition was moved to subclause 6.9. All subsequent subclauses were renumbered.

(19) Subclause 7.2.4—Deleted qualification of UT Technicians to FEMA requirements.

(20) Subclause 7.8—Revised to require MT of weld tab removal sites only where repaired by additional welding.

(21) Table A.2—Revised to address minimum CVN toughness.

(22) Figure A.1—Revised to allow thicker test plate for SAW.

(23) Clause B8—Provision added for applications with LAST below +50°F [+10°C].

(24) Figure B.1—Location of the CVN specimen was corrected with references to Figure B.2 and B.3.

(25) Annex C—Annex left blank to avoid confusion with the Commentary section. Contents of previous Annex C were moved to Annex D; subsequent annexes were renumbered.

(26) Subclause D3.2.3—Revised so that removal of steel backing is at the Contractor's option.

(27) Subclause D3.2.4—Revised to include a maximum depth for backgouging.

(28) Subclause D4.1—Revised so visual inspection has tighter restrictions.

(29) Subclause D4.2—Added a provision for the removal of the backing to prevent interference with testing.

(30) Figure D.1—Clarified and added tolerances.

(31) Subclause C-4.2—New commentary added on tapered transitions.

(32) Subclause C-6.3.5—Clarified acceptability of CVN tests with higher energy levels or at lower temperatures than those specified.

(33) Subclause C-6.12—Content from previous edition was moved to subclause C-6.9. All subsequent commentary subclauses were renumbered.

(34) Subclause C-6.15.4.3—Added reference to D1.1 for repairs requiring Engineer's approval and repair requirements.

(35) Figure C-6.3—Note requiring Engineer's approval for welding at k-area was removed.

(36) Subclause C-A5.2—New commentary explaining deletion of the two layer per pass requirement.

Background. Damage sustained by welded steel moment-frame buildings in the 1994 Northridge earthquake, and extensive research conducted by the FEMA/SAC program following that earthquake, demonstrated that in order to obtain adequate performance of welded steel structures under conditions of severe earthquake-induced inelastic straining, additional controls on design, detailing, materials, workmanship, testing, and inspection are necessary. This research resulted in substantive changes to the AISC Seismic Provisions, which control the design of steel Seismic Force Resisting Systems (SFRS) designed to withstand severe inelastic straining as well as certain aspects of the materials and detailing of these systems. The provisions contained in this standard complement the AISC Seismic Provisions and are intended to ensure that welded joints that are designed to undergo significant repetitive inelastic strains as a result of earthquakes, or that are used to connect members designed to resist such inelastic strains, have adequate strength, notch toughness, and integrity to perform as intended. This code, together with AWS D1.1/D1.1M, specifies the acceptable materials, procedures, and workmanship for constructing welded joints in SFRS designed in accordance with the AISC Seismic Provisions as well as the procedures and acceptance criteria for quality control and quality assurance inspection of welded joints in the SFRS. In some regions of the U.S., with low risk of intense earthquake shaking, building codes permit design of steel Seismic Force Resisting Systems that do not conform to the requirements of the AISC Seismic Provisions. The requirements of this code apply only to the SFRS in structures designed in accordance with the AISC Seismic Provisions and need not be applied to structures not designed to those provisions.

Commentary. The Commentary is nonmandatory and is intended only to provide insight, information, and provision rationale.

Mandatory Annexes. These additions to the code are requirements that supplement the text.

Errata. It is the Structural Welding Committee's Policy that all errata should be made available to users of the code. Therefore, any significant errata will be published in the Society News Section of the AWS *Welding Journal* and posted on the AWS web site at: http://www.aws.org/technical/d1/.

Suggestions. Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D1 Committee on Structural Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Table of Contents

Page No.

List of Tables

Table **Page No.**

List of Figures

Figure **Page No.**

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Structural Welding Code—Seismic Supplement

1. General Requirements

1.1 Applicability

The provisions of this code supplement the provisions of AWS D1.1/D1.1M, *Structural Welding Code—Steel*, and shall apply to the design, fabrication, quality control, and quality assurance of welded joints designed in accordance with the AISC *Seismic Provisions for Structural Steel Buildings.* All provisions of AWS D1.1/D1.1M for statically loaded structures shall apply to the designated welds, except as specifically modified herein.

1.2 Responsibilities

1.2.1 Engineer's Responsibilities. In addition to the items listed in AWS D1.1/D1.1M, the Engineer shall provide the following information in the Contract Documents:

(1) Connection configuration, material specifications, and part sizes required to provide the needed seismic performance (see 1.3)

(2) Identification of members that comprise the Seismic Force Resisting System (SFRS) and that are subject to the provisions of this code (see 3.1)

(3) The location of the Protected Zone for members of the SFRS (see 3.3)

(4) Welds designated as "Demand Critical" and subject to specific provisions of this code (see 3.2)

(5) Locations where the removal of backing is required (see 6.7)

(6) Locations where fillet welds are required when backing is permitted to remain (see 6.9)

(7) Locations where the removal of weld tabs is required (see 6.11.3 and 6.11.4)

(8) Locations where fillet welds are required to reinforce groove welds, or to improve connection geometry (see 6.8)

(9) Locations of access holes and the required shape, whether standard AWS D1.1/D1.1M geometry (see 6.10.1.1), standard alternate geometry (see 6.10.1.2), or a special geometry designated by the Engineer (see 6.10.1.3)

(10) The Lowest Anticipated Service Temperature (LAST) of the steel structure for structures that are not normally enclosed and maintained at a temperature of 50°F [10°C] or higher (see 3.5 and 6.3.6)

(11) Butt joints subject to tension where tapered transitions are required (see 4.2)

(12) Those joints or groups of joints in which a specific assembly order, welding sequence, welding technique, or other special precautions are required (see AWS D1.1/D1.1M subclauses 2.2.3 and 5.21)

(13) Quality Assurance Plan (QAP) for the project (see 3.4 and 7.1)

(14) Any additional provisions applicable to the specific project not governed by AWS D1.1/D1.1M or this code.

1.2.2 Contractor's Responsibilities. When this code or the Quality Assurance Plan (QAP) requires the Contractor to retain documentation, the document(s) shall be retained for at least one year after substantial completion of construction. The documents shall be made available to the Engineer, Inspector, or both when requested. When the QAP requires submittal of document(s), submittals shall be made to the Engineer and copies of submittals shall be retained by the Contractor.

1.2.2.1 AWS A5 Specification Certification. Certificates of Conformance for electrodes, fluxes, and shielding gases shall satisfy the applicable AWS A5 specification requirements.

1.2.2.2 Certification of Heat Input Envelope Testing. Certifications that filler metals used to make Demand Critical welds meet the Heat Input Envelope Testing requirements of 6.3.5 and Annex A shall be provided by the filler metal manufacturer. Should the filler metal manufacturer not supply such certifications, the

Contractor shall have the necessary testing performed and provide the test reports.

1.2.2.3 Product Data Sheets. For GMAW performed with composite (cored) electrodes and for all FCAW and SMAW electrodes, the filler metal manufacturer's data sheets or catalog data supplied with Welding Procedure Specifications (WPSs) shall show the recommended or typical welding parameter combinations. The manufacturer's recommendations for storage, exposure, and baking (if applicable) shall also be provided.

1.2.2.4 Hydrogen Content. The Contractor shall retain documentation that the filler metals comply with the hydrogen requirements of 6.3.2, as applicable.

1.2.2.5 Extended Exposure Capability of FCAW Filler Metals. When limits of filler metal exposure are extended in accordance with 6.4.3, documentation of testing in accordance with Annex E shall be retained by the Contractor.

1.2.2.6 Welding Procedure Specifications (WPSs). The Contractor shall be responsible for all WPSs.

1.2.2.7 Supplemental Welder Qualification Testing Documentation. The Contractor shall retain documentation that welders performing Demand Critical complete joint penetration groove welding of beam bottom flange to column T-joints have passed the Supplemental Welder Qualification for Restricted Access Welding test described in Annex D.

1.3 Limitations

This code is intended to apply to the following:

(1) Structures made of steels with minimum specified yield strengths of 70 ksi [480 MPa] or less

(2) Structures that utilize steel with a minimum specified yield strength of 55 ksi [380 MPa] or less for the beams or braces in which inelastic behavior is expected

1.4 Welding Symbols

Welding symbols shall be those shown in the latest edition of AWS A2.4, *Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions shall be fully explained by added notes or details.

1.5 Safety Precautions

Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal, state, and local regulations.

1.6 Standard Units of Measurement

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

2. Normative References

The standards listed below contain provisions, which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

American Welding Society (AWS) Standards:[1]

(1) AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

(2) AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

(3) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(4) AWS A5.01M/A5.01, *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

(5) AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*

(6) AWS A5.5/A5.5M, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*

(7) AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

(8) AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

(9) AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*

(10) AWS A5.23/A5.23M, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

(11) AWS A5.25/A5.25M, *Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*

(12) AWS A5.26/A5.26M, *Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*

(13) AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

(14) AWS A5.29/A5.29M, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*

(15) AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

(16) AWS B5.1, *Specification for the Qualification of Welding Inspectors*

(17) AWS C4.1, *Criteria for Describing Oxygen-Cut Surfaces, and Oxygen Cutting Surface Roughness Gauge*

(18) AWS D1.1/D1.1M, *Structural Welding Code—Steel*

(19) AWS QC1, *Standard for AWS Certification of Welding Inspectors*

American Institute of Steel Construction (AISC) Standards:[2]

(1) AISC 341, *Seismic Provisions for Structural Steel Buildings*

(2) AISC 358, *Prequalified Connections for Special and Intermediate Moment Frames for Seismic Applications*

(3) AISC 360, *Specification for Structural Steel Buildings*

[1] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] AISC standards are published by the American Institute of Steel Construction, One East Wacker Drive, Suite 700, Chicago, IL 60601-1802.

American Society for Nondestructive Testing (ASNT) Standards:[3]

(1) ASNT SNT-TC-1A, *Recommended Practice for the Qualification and Certification of Nondestructive Testing Personnel*

(2) ASNT CP-189, *Standard for the Qualification and Certification of Nondestructive Testing Personnel*

Canadian Standards Association (CSA):[4]

(1) CSA W178.2, *Certification of Welding Inspectors*

[3] ASNT standards are published by the American Society for Nondestructive Testing, P.O. Box 28518, 1711 Arlingate Lane, Columbus, OH 43228-0518.

[4] CSA standards are published by the Canadian Standards Association, 5060 Spectrum Way, Suite 100, Mississauga, Ontario L4W 5N6, Canada.

3. Terms and Definitions

AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terms and definitions used herein. However, for the purposes of this document, the following terms and definitions apply:

3.1 Seismic Force Resisting System (SFRS)

The assembly of structural elements in the building that resists seismic loads, as indicated by the Engineer in the Contract Documents. Included in the SFRS are the columns, beams, girders and braces, and the connections between these elements, specifically designed to resist seismic loads, either alone or in combination with other loads. The SFRS does not include other structural members not designed to resist seismic loads.

3.2 Demand Critical Welds

Welds designated by the Engineer in the Contract Documents, and required to meet specific requirements of this code.

3.3 Protected Zone

That portion of a member of the SFRS, designated by the Engineer in Contract Documents in which inelastic straining is anticipated to occur and to which special limitations in these provisions apply with regard to attachments and fabrication.

3.4 Quality Assurance Plan (QAP)

The written description of qualifications, procedures, quality inspections, resources, and records to be used to provide assurance that the structure complies with the Engineer's quality requirements, specifications, jurisdictional requirements, and Contract Documents.

3.5 Lowest Anticipated Service Temperature (LAST)

The lowest one (1) hour average temperature with a 100-year mean recurrence interval.

3.6 k-Area

The region of the web that extends from the tangent point of the web and the flange-web fillet (AISC *k* dimension) a distance 1-1/2 in [40 mm] into the web beyond the *k* detail dimension.[5]

[5] See AISC *Specification for Structural Steel Buildings* for formal definition of *k* detail dimension.

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4. Welded Connection Details

4.1 Corner Clips of Continuity Plates and Stiffeners

Corners of continuity plates and stiffeners shall be clipped as follows:

4.1.1 Along the Web. The corner clip along the web shall be detailed so that the clip extends a distance of at least 1-1/2 in [40 mm] beyond the published *k* detail dimension for the rolled shape.[6]

4.1.2 Along the Flange. The corner clip along the flange shall be detailed so that the clip does not exceed a distance of 1/2 in [12 mm] beyond the published k_1 dimension.[7]

[6] See AISC *Specification for Structural Steel Buildings* for formal definition of *k* detail dimension.

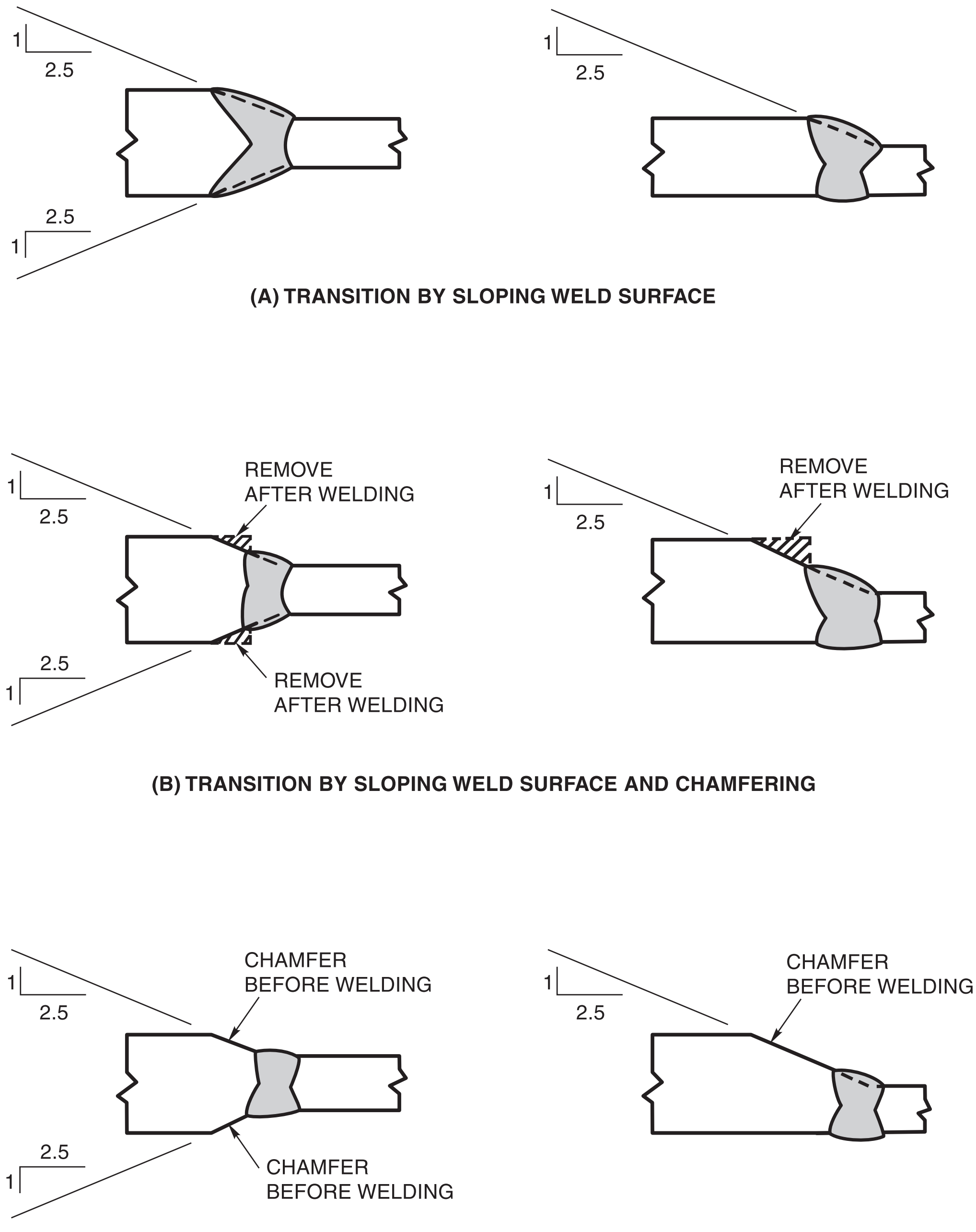
[7] See the AISC *Steel Construction Manual* Part 1 for k_1 dimensions.

4.1.3 Facilitating Suitable Weld Terminations. The corner clip shall be detailed to facilitate suitable weld terminations of both the flange weld and the web weld.

4.1.4 Curved Corner Clips. Curved corner clips, if used, shall have a minimum radius of 1/2 in [12 mm].

4.2 Transitions in Thicknesses and Widths

When butt joints subject to tension are required to be tapered, transitions shall be made in such manner that the slope in the transition does not exceed 1 in 2-1/2 (see Figure 4.1 for thickness transitions and Figure 4.2 for width transitions). The transition shall be accomplished by chamfering the thicker part, tapering the wider part, sloping the weld metal or by a combination of these.



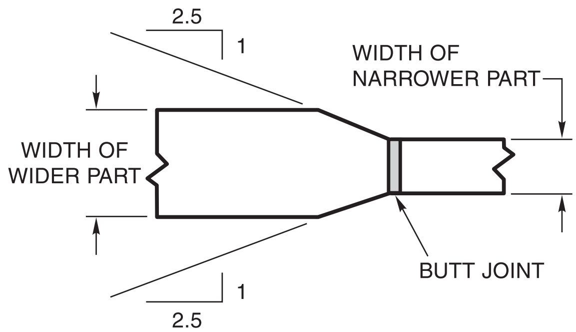
(A) TRANSITION BY SLOPING WELD SURFACE

(B) TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING

(C) TRANSITION BY CHAMFERING THICKER PART

Source: Reproduced from AWS D1.1/D1.1M:2006, *Structural Welding Code—Steel*, Figure 2.2, Miami: American Welding Society.

Figure 4.1—Transition of Butt Joints in Parts of Unequal Thicknesses



Source: Reproduced from AWS D1.1/D1.1M:2006, *Structural Welding Code—Steel*, Figure 2.3, Miami: American Welding Society.

Figure 4.2—Transition of Butt Joints in Parts of Unequal Widths

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5. Welder Qualification

5.1 Supplemental Welder Qualification Testing

5.1.1 Required Tests. In addition to the requirements of AWS D1.1/D1.1M Clause 4, welders shall pass the Supplemental Welder Qualification for Restricted Access Welding as prescribed in Annex D, when the welder is required to make welds meeting all of the following requirements:

(1) The weld is Demand Critical.

(2) The weld joins the bottom beam flange to the column flange.

(3) The weld must be made by welding through a beam web weld access hole.

5.1.2 Testing Parameters. The Supplemental Welder Qualification for Restricted Access Welding test shall be performed using the welding process that will be used in the work. The test shall be performed using a deposition rate equal to, or greater than, that to be used in production.

5.1.3 Backing. The Supplemental Welder Qualification for Restricted Access Welding test shall use the type of backing to be used on the project, except that, tests performed with no backing shall qualify the welder to use steel backing in production, but the reverse shall not be permitted.

If other than steel backing is used, or if no backing is used, the welder shall be qualified using the maximum root opening that will be permitted in production. If the project will use no backing, no backing shall be permitted on the qualification test.

5.1.4 Tack Welders. Tack welders are not required to perform the Supplemental Welder Qualification for Restricted Access Welding test described in Annex D.

5.2 Welder Qualification Period

The qualification for welding personnel using the Supplemental Welder Qualification for Restricted Access Welding prescribed in Annex D shall remain valid for 36 months, providing the continuity requirements for process use of AWS D1.1/D1.1M are met. Should the 36-month period elapse while welding on the project, the Supplemental Welder Qualification for Restricted Access Welding qualification shall remain valid unless there is a specific reason to question the welder's ability.

5.3 Welder Performance Qualification Record Information

Welder Performance Qualification Records for the Supplemental Welder Qualification for Restricted Access Welding described in Annex D shall, as a minimum, provide all applicable essential variables contained in Table 4.11 of AWS D1.1/D1.1M, and the following:

(1) Type of backing, if used

(2) Maximum root opening (if steel backing is not used)

(3) Maximum deposition rate

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6. Fabrication

6.1 Welding Procedure Specifications (WPSs)

6.1.1 General. WPSs shall be prequalified, or shall be qualified by test, in accordance with applicable AWS D1.1/D1.1M requirements.

6.1.2 WPS Content. The WPS shall specify all applicable essential variables of AWS D1.1/D1.1M. For Demand Critical welds, the WPS shall additionally list the following essential variables:

(1) Electrode manufacturer and trade name;

(2) For FCAW, SAW, and GMAW performed with composite (metal cored) electrodes, WPSs shall list one or more combinations of welding variables that produce heat inputs within the limits of 6.1.3.

6.1.3 Heat Input Limits. Acceptable heat input limits on WPSs for Demand Critical welds shall include the following, at the Contractor's option:

(1) The heat input range qualified by testing in accordance with Annex A

(2) The heat input range prescribed in AWS A5.20/A5.20M:2005 Clause 17 for carbon steel FCAW electrodes classified with the supplemental designator "-D"

(3) The heat input range prescribed in AWS A5.20/A5.20M:2005 Clause 17 for the following filler metals when optionally tested to the requirements of the "-D" supplemental designator:

(a) Low alloy FCAW electrodes, classified to AWS A5.29/A5.29M;

(b) Carbon steel GMAW composite (metal cored) electrodes, classified to AWS A5.18/A5.18M, and low alloy GMAW composite (metal cored) electrodes, classified to AWS A5.28/A5.28M;

(c) Carbon steel SAW electrode/flux combinations, classified to AWS A5.17/A5.17M, and low alloy SAW electrode/flux combinations, classified to AWS A5.23/A5.23M.

6.2 Welding Processes

6.2.1 Approved Processes for Demand Critical Welds. SMAW, GMAW (except short circuit transfer), FCAW, and SAW may be used to make Demand Critical welds governed by this code. Other processes may be used, provided that one or more of the following criteria is met:

(1) The process is part of the prequalified connection details, as listed in AISC Seismic Provisions;

(2) The process is permitted for the connection in AISC 358;

(3) The process was used to perform a satisfactory connection qualification test in accordance with AISC Seismic Provisions;

(4) The process is approved by the Engineer.

6.2.2 Air Velocity Limits

6.2.2.1 Gas-Shielded Processes. Welding with the GMAW and FCAW-G processes shall not be performed in winds exceeding 3 mph [5 kph]. Windscreens or shelters may be used to shield the welding operation from excessive wind.

6.2.2.2 Non Gas-Shielded Processes. SMAW, FCAW-S, and SAW may be performed without limitation to air velocity, provided the welds meet the visual acceptance criteria.

6.3 Filler and Weld Metal

All welds governed by this code shall comply with all the requirements of 6.3, except that the requirements of 6.3.5, 6.3.6, 6.3.7, and 6.3.8 shall apply only to Demand Critical welds.

6.3.1 AWS A5 Specification Properties. Filler metals shall meet the requirements of Table 6.1 as determined from testing in accordance with the applicable AWS A5 specification.

6.3.2 Diffusible Hydrogen Level. All welding electrodes and electrode-flux combinations shall meet the requirements of Table 6.3.

6.3.3 Certification of AWS A5 Specification Properties and Diffusible Hydrogen. The manufacturer's typical Certificate of Conformance shall be considered adequate proof that the supplied electrode or electrode-flux combination meets the requirements of 6.3.1 and 6.3.2. No testing of filler metal samples or of production welds shall be required.

6.3.4 Intermix of FCAW-S Filler Metal. When FCAW-S filler metals are used in combination with filler metals for other processes, including FCAW-G, supplemental notch toughness testing shall be conducted in accordance with one or more of the following:

(1) Tests as described in Annex B;

(2) PQR tests that contain intermixed weld metal, wherein CVN test specimens have been taken from the intermixed zone;

(3) Alternative tests, as approved by the Engineer.

Regardless of the testing method used, the testing shall demonstrate that the acceptance criteria of Annex B are met.

6.3.5 WPS Heat Input Envelope Testing Properties. Filler metals for Demand Critical welds shall provide the mechanical properties in Table 6.2, based upon the WPS Heat Input Envelope Testing prescribed in Annex A, except the following filler metals shall be exempted from the testing required by Annex A when LAST is equal to or greater than +50°F [+10°C]:

(1) SMAW electrodes classified as E7018, E7018-X, in AWS A5.1/A5.1M, and E7018-C3L, E8018-C3 in AWS A5.5/A5.5M (see 6.3.8.2);

(2) Solid GMAW electrodes (see 6.3.8.2);

(3) Carbon steel FCAW electrodes classified with the "-D" designator as described in AWS A5.20/5.20M;

(4) Low alloy FCAW electrodes, carbon steel and low alloy composite (metal cored) GMAW electrodes, and carbon steel and low alloy electrode/flux SAW combinations that have been optionally tested by the filler metal manufacturer in accordance with AWS A5.20/A5.20M:2005 Clause 17 for the "-D" designator. The test plate for the "-D" testing of SAW filler metals may be performed on a 1 in [25 mm] test plate instead of the 3/4 in [18 mm] test plate mandated by AWS A5.20/A5.20M.

6.3.6 Lowest Anticipated Service Temperature Applications. For Demand Critical welds in applications where the Seismic Force Resisting System is subjected to service temperatures below +50°F [+10°C] following completion of the structure, the minimum CVN of 40 ft·lbf [54 J] as prescribed by 6.3.5 shall be provided at a test temperature not more than 20°F [10°C] above the Lowest Anticipated Service Temperature. The exceptions in 6.3.5 and 6.3.8.2 shall not apply when LAST is less than +50°F [+10°C].

6.3.7 Testing Source. The WPS Heat Input Envelope Testing of Filler Metals, required for Demand Critical welds and described in Annex A, shall be performed by the filler metal manufacturer, by the Contractor, or by a third party acceptable to the Engineer. The Contractor shall be responsible to ensure that this testing has been performed for the filler metals to be used, regardless of the testing source.

6.3.8 Filler Metal Production Lot Control. Each production lot of filler metal used to make Demand Critical welds shall be tested in conformance with the applicable AWS A5 specification filler metal classification tests. In addition to the standard AWS A5 specification testing, high and low heat input testing shall be performed in accordance with either Annex A, or A5.20/A5.20M:2005 Clause 17 for the "-D" designator, at the Contractor's option.

Production lots shall be as defined in AWS A5.01M/A5.01, *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*. Production lots shall meet the following requirements:

(1) Class C3 or C4 for SMAW electrodes

(2) Class S3 or S4 for solid electrodes for GMAW and SAW

(3) Class T3 or T4 for FCAW and composite electrodes for GMAW and SAW

(4) Class F2 for SAW fluxes

6.3.8.1 Alternative to Production Lot Testing. Filler metals produced by manufacturers audited and approved by one or more of the following agencies shall be exempt from production lot testing, provided a minimum of 3 different lots of material, as defined in 6.3.8, for each trade name and diameter to be used in production, are first tested in accordance with Annex A:

(1) American Bureau of Shipping (ABS)

(2) Lloyd's Register of Shipping

(3) American Society of Mechanical Engineers (ASME)

(4) U.S. Department of Defense

(5) A quality assurance program acceptable to the Engineer

To remain exempt from production lot testing, the manufacturer shall perform the test as described in Annex A, on at least one lot of material, at a frequency not to exceed three years, for each trade name and diameter of electrode to be used in production.

6.3.8.2 Exceptions. For LAST greater than or equal to +50°F [+10°C], SMAW with E7018, E7018-X, E7018-C3L, and E8018-C3 electrodes, and GMAW solid electrodes shall be exempted from lot testing when the CVN toughness of the weld metal deposited with the electrode equals or exceeds 20 ft·lbs [27 J] at a temperature not exceeding 0°F [–18°C], when tested in accordance with the applicable AWS A5 filler metal specification. The manufacturer's Certificate of Conformance shall be considered sufficient evidence of meeting this requirement.

6.4 FCAW Electrode Packaging, Storage, and Exposure

The following provisions shall be applicable for Demand Critical welds:

6.4.1 Packaging Condition. Electrodes shall be provided in protective packaging that limits the ability of the electrode to absorb moisture. When removed from the packaging, the electrode shall be capable of depositing weld metal with a maximum diffusible hydrogen content not to exceed the limits of 6.3.2. Electrode from packaging that has been punctured or torn shall be dried in accordance with the electrode manufacturer's recommendations, or shall not be used for Demand Critical welds.

6.4.2 Modification of Electrodes. Modification or lubrication of the electrode after manufacture is prohibited, except that drying is permitted as recommended by the manufacturer.

6.4.3 Exposure Time Limits for FCAW electrodes. After removal from protective packaging, the permissible atmospheric exposure time of FCAW electrodes shall be limited as follows:

(1) Exposure shall not exceed the electrode manufacturer's guidelines, when the guidelines are based upon electrode exposure tests conducted in accordance with Annex E.

(2) In the absence of test data required in (1), the electrode may be tested in accordance with Annex E, and the results of such tests used as the basis for the exposure limits.

(3) In the absence of test data required by (1) or (2), the total accumulated exposure time for FCAW electrodes shall not exceed 72 hours. Storage time in a protective package or cabinet shall not be included in the accumulated exposure time.

6.4.4 Overexposed FCAW Electrode. Electrodes that have been exposed to the atmosphere for periods that exceed the limits of 6.4.3 shall be dried in accordance with the electrode manufacturer's recommendations, or shall not be used for Demand Critical welds. The electrode manufacturer's recommendations shall include time, temperature, and number of drying cycles permitted.

6.5 Maximum Interpass Temperature

6.5.1 Standard Maximum Interpass Temperature. The maximum interpass temperature shall not exceed 550°F [300°C], unless an alternate value is qualified in accordance with 6.5.2. The maximum interpass temperature shall be measured at a distance of 1 in to 3 in [25 mm to 75 mm] from the joint.

6.5.2 Alternative Maximum Interpass Temperature. The temperature limit of 6.5.1 may be increased by qualification testing. The qualification testing shall be performed in accordance with AWS D1.1/D1.1M. The maximum heat input to be used in production shall be used in the qualification testing. The qualified maximum interpass temperature shall be the lowest interpass temperature used for any pass during qualification testing. The weld metal and HAZ shall be tested. The weld metal shall meet all the mechanical properties required by 6.3.1 and 6.3.5, as applicable. The HAZ CVN toughness shall be tested in accordance with AWS D1.1/D1.1M Clause 4, Qualification, and shall meet a minimum requirement of 20 ft·lbf [27 J] at 70°F [20°C] with specimens taken at both 1 mm and 5 mm from the fusion line. The steel used for the qualification testing shall be of the same type and grade as will be used in production.

6.6 Tack Welds to Steel Backing in the Protected Zone

Tack welds between backing and the beam flange outside the weld joint shall be prohibited. Tack welds that attach steel backing to groove welds in the Protected Zone shall be placed within the weld joint, when practicable, with the following exception: steel backing may be tack welded to columns for beam to column welds.

6.7 Removal of Backing and Weld Root Treatment

When fusible (steel) backing is required to be removed, removal shall be by air carbon arc cutting (CAC-A), plasma arc gouging (PAC-G), grinding, chipping, or thermal cutting. The process shall be controlled to minimize errant gouging. After backing removal (both for steel and nonfusible backing), the weld root shall be backgouged to sound metal. Backgouged joints shall be filled with weld metal, as necessary, to achieve at least a flush condition. The weld shall be deposited in accordance with an applicable WPS. Gouges that remain after any backwelding or fillet welding is performed shall be repaired. Notches and gouges not greater than 1/16 in [1.5 mm] deep shall be faired to a slope not greater than 1:5. Deeper notches shall be repaired by welding in accordance with an applicable WPS.

6.8 Reinforcing Fillet Welds at Removed Weld Backing Locations

When reinforcing fillet welds are required at locations where steel backing has been removed, the minimum size shall be 5/16 in [8 mm]. The leg of the fillet adjacent to the beam flange shall be such that the fillet toe is located on base metal, except that if the weld root and base metal is ground smooth after removal of backing, the fillet need not extend to the base metal (see Figure 6.1).

6.9 Fillet Welds at Left-in-Place Steel Backing

6.9.1 Minimum Fillet Weld Size. When a fillet weld is required between the left-in-place steel backing and the column, the minimum size shall be 5/16 in [8 mm].

6.9.2 Prohibited Welds on Left-in-Place Steel Backing. Steel backing at beam flange to column flange joints shall not be welded to the underside of the beam flange. Tack welds shall not be permitted in this area.

6.9.3 Correction of Errors. If fillet welds or tack welds are placed between the backing and the beam flange in error, they shall be repaired as follows:

(1) The weld shall be removed such that the fillet weld or tack weld no longer attaches the backing to the beam flange.

(2) The surface of the beam flange shall be ground flush and shall be free of defects.

(3) Any gouges or notches shall be repaired in accordance with 6.15.4.

6.10 Weld Access Holes

Weld access holes for all Demand Critical welds shall conform to the following:

6.10.1 Shape

6.10.1.1 Standard AWS D1.1/D1.1M Geometry. Unless otherwise specified in Contract Documents, all weld access holes shall meet the dimensions and tolerances of AWS D1.1/D1.1M or AISC 360. At the option of the Contractor, the geometry of 6.10.1.2 may be substituted for the 6.10.1.1 geometry.

6.10.1.2 Alternate Geometry. When required by Contract Documents, the weld access hole dimensions and tolerances, and geometry shall comply with Figure 6.2.

6.10.1.3 Special Geometry. When a special geometry is required by Contract Documents, the weld access hole geometry shall comply with those dimensions and tolerances specified.

6.10.2 Quality Requirements for Weld Access Holes

6.10.2.1 Surface Roughness. Except for access holes using AWS D1.1/D1.1M standard geometry, or when otherwise specified by the Engineer, the weld access hole finish shall have a surface roughness of not more than 500 μin [13 μm]. AWS C4.1, *Criteria for Describing Oxygen-Cut Surfaces, and Oxygen Cutting Surface Roughness Gauge*, Sample 4, may be used as a guide for evaluating surface roughness of these surfaces.

6.10.2.2 Notches and Gouges. Notches or gouges in the weld access hole, including those from thermal cutting and misaligned saw cuts, shall be removed by grinding, faired to a slope of not more than 1:5 against a straight cut surface, or to a radius of not less than 3/8 in [10 mm] if in the curved portion of the cut surface. The depth of notches and gouges that may be repaired by grinding is not limited, provided the final shape of the weld access hole meets the required dimensions, tolerances, and profiles.

6.10.2.3 Repair of Notches by Welding. Notches deeper than those that can be repaired by grinding (as defined in 6.10.2.2) may be repaired by welding. Prior to welding, the notch or gouge shall be ground to provide a smooth contour with a radius not less than 1/4 in [6 mm]. The repair area shall be preheated to a temperature of not less than 150°F [65°C]. A written repair WPS for this application shall be followed. Following completion of welding, the area shall be ground, and the overall area made smooth and flush to meet the contour and finish requirements for the access hole, with fairing of the welded surface to adjoining surfaces.

6.11 Weld Tabs

6.11.1 Minimum Weld Tab Length. Where practicable, weld tabs shall extend a minimum of 1 in [25 mm] or the thickness of the part, whichever is greater, beyond the edge of the joint. Weld tab length need not exceed 2 in [50 mm]. Where there is inadequate access for weld tabs, such as with closely spaced pieces or pieces intersecting at acute angles, weld ends may be cascaded for approximately one weld size.

6.11.2 Tack Welds Attaching Weld Tabs. Tack welds attaching weld tabs in the Protected Zone shall be made within the joint, and shall meet the requirements of 6.16.

6.11.3 Weld Tab Removal—General. When weld tabs are required by Contract Documents to be removed, weld tabs shall be removed and the end of the weld finished. Removal shall be by air carbon arc cutting (CAC-A), grinding, chipping, or thermal cutting. The process shall be controlled to minimize errant gouging. The edges where weld tabs have been removed shall have a surface roughness of not more than 500 μin [13 μm]. AWS C4.1, *Criteria for Describing Oxygen-Cut Surfaces, and Oxygen Cutting Surface Roughness Gauge*, Sample 4, may be used as a guide for evaluating surface roughness of these surfaces. Grinding to a flush condition is not required. The contour of the weld shall provide a smooth transition, free of notches and sharp corners. At T-joints, a minimum radius in the corner need not be provided. The weld end shall be free of defects. Defects not greater than 1/16 in [1.5 mm] deep shall be removed by grinding and faired to a slope not greater than 1:5. Other defects shall be excavated and repaired by welding in accordance with an applicable WPS (see Figure 6.3).

6.11.4 Weld Tabs for Continuity Plates. Weld tabs for continuity plates shall not be used at the end of the weld adjacent to the column web-to-flange juncture, except when permitted or required by the Engineer. Unless specified to be removed by the Engineer, weld tabs shall not be removed when used in this location.

6.12 End Dams

6.12.1 Material. End dams may be metallic or nonmetallic.

6.12.2 Placement. End dams shall not be placed at either end of the weld joint, except as follows: end dams may be placed at the outboard ends of the weld tabs, provided the weld tabs are removed upon completion of the weld (see Figure 6.4).

6.13 Welder Identification

The Contractor shall establish and implement a means by which the welder(s) welding on each joint can be identified and associated with the specific joint. Stamps, if used, shall be the low-stress type.

6.14 Bottom Flange Welding Sequence

Complete joint penetration groove welds of beam bottom flanges to column flanges, or to continuity plates, using weld access holes shall be sequenced as follows:

(1) As far as is practicable, starts and stops shall not be directly under the beam web.

(2) Each layer shall be completed across the full width of the flange before beginning the next layer.

(3) For each layer, the weld starts and stops shall be on the opposite side of the beam web, as compared to the previous layer.

6.15 Protected Zone

6.15.1 Attachments and Welds. Welded attachments, including stud welds and fasteners for the connection of other materials, shall be prohibited within the Protected Zone. Arc spot welds (puddle welds) for the attachment of metal decking shall be permitted in the Protected Zone.

6.15.2 Erection Aids. If erection aids are required to be attached within the Protected Zone, the Contractor shall obtain the Engineer's approval for the use of such attachments.

6.15.3 Removal of Welds in Protected Zone. When welds in the Protected Zone are required to be removed, removal shall be by air carbon arc cutting (CAC-A), grinding, chipping, or thermal cutting. The process shall be controlled to minimize errant gouging. After removal, the area shall be ground smooth and free of defects.

6.15.4 Repair of Gouges and Notches. Gouges and notches in the Protected Zone shall be repaired as follows:

6.15.4.1 Grinding. When gouges and notches are repaired by grinding, the ground area shall provide a gradual taper to the surface of the base metal. In the direction parallel to the member axis, the taper shall not be greater than 1:5. In the direction transverse to the member axis, the taper shall not be greater than 1:2.5.

6.15.4.2 Repair Welding of Gouges and Notches. When repairs require welding, the notch or gouge shall be removed and ground to provide a smooth radius of not less than 1/4 in [6 mm] in preparation for welding. Welding shall be done in accordance an applicable WPS. Preheat shall be in accordance with AWS D1.1/D1.1M, but shall not be less than 150°F [65°C]. Electrodes shall comply with 6.3. Following welding, the repair weld shall be ground to a smooth contour with a surface roughness not to exceed 500 μin [13 μm]. AWS C4.1, *Criteria for Describing Oxygen-Cut Surfaces, and Oxygen Cutting Surface Roughness Gauge*, Sample 4, may be used as a guide for evaluating surface roughness of these surfaces. After repair, the area shall be inspected using magnetic particle testing (MT). The resultant thickness of the repaired area shall be no less than the base metal thickness less 1/16 in [1.5 mm].

6.15.4.3 Engineer Approval. Where repairs require the Engineer's approval, complete instructions and procedures shall be developed by the Contractor and approved by the Engineer before repairs are made.

6.16 Tack Welding Requirements

6.16.1 Preheat. Preheat for all tack welds shall be as required by the WPS.

6.16.2 Placement of Tack Welds. In the Protected Zone, unless specifically required or permitted by the Engineer and shown on detail drawings, tack welds shall be prohibited outside the weld joint.

6.16.3 Removal of Improperly Placed Tack Welds. Improperly placed tack welds shall be removed by grinding. Gouges or notches shall be repaired in accordance with 6.15.4.

Table 6.1
Filler Metal Classification Properties

Property	70 ksi [480 MPa] Classification	80 ksi [550 MPa] Classification
Yield Strength, ksi [MPa]	58 [400] min.	68 [470] min.
Tensile Strength, ksi [MPa]	70 [480] min.	80 [550] min.
Elongation (%)	22 min.	19 min.
CVN Toughness, ft·lbf [J][a]	20 [27] min. @ 0°F [–18°C]	20 [27] min. @ 0°F [–18°C]

[a] Filler metals classified as meeting 20 ft·lbf [27 J] min. at a temperature lower than 0°F [–18°C] also meet this requirement.

Table 6.2
Mechanical Properties for Demand Critical Welds

Property	70 ksi [480 MPa] Classification	80 ksi [550 MPa] Classification
Yield Strength, ksi [MPa]	58 [400] min.	68 [470] min.
Tensile Strength, ksi [MPa]	70 [480] min.	80 [550] min.
Elongation (%)	22 min.	19 min.
CVN Toughness, ft·lbf [J][a, b]	40 [54] min. @ 70°F [20°C]	40 [54] min. @ 70°F [20°C]

[a] For LAST of +50°F [+10°C]. For LAST less than + 50°F [+10°C], see 6.3.6.
[b] Tests conducted in accordance to Annex A meeting 40 ft·lbf [54 J] min. at a temperature lower than +70°F [+20°C] also meet this requirement.

Table 6.3
Diffusible Hydrogen Testing Requirements

Process	Filler Metal Specification	Filler Metal Type	Standard Test	Optional Test[e]
SMAW	A5.1/A5.1M	Carbon Steel	Moisture Content per AWS A5.1	H16 per AWS A4.3[a]
	A5.5/A5.5M	Low Alloy	Moisture Content per AWS A5.5	
GMAW—solid electrode	A5.18/A5.18M	Carbon Steel	Exempt[d]	
	A5.28/A5.28M	Low Alloy	Exempt[d]	
GMAW— composite (metal cored) electrode	A5.18/A5.18M	Carbon Steel	H16 per AWS A4.3[a]	None
	A5.28/A5.28M	Low Alloy	H16 per AWS A4.3[a]	None
FCAW	A5.20/A5.20M	Carbon Steel	H16 per AWS A5.20[b]	None
	A5.29/A5.29M	Low Alloy	H16 per AWS A5.29[c]	None
SAW	A5.17/A5.17M	Carbon Steel	H16 per AWS A4.3[a]	None
	A5.23/A5.23M	Low Alloy	H16 per AWS A4.3[a]	None
EGW with solid electrodes	A5.26/A5.26M	Carbon Steel and Low Alloy	Exempt[d]	
EGW with composite electrodes	A5.26/A5.26M	Carbon Steel and Low Alloy	As agreed upon between the Contractor and the Engineer.	None
ESW	A5.25/A5.25M	Carbon Steel and Low Alloy	As agreed upon between the Contractor and the Engineer.	None

[a] AWS A4.3 refers to AWS A4.3-93, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.
[b] A5.20 refers to AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, Clause 16.
[c] A5.29 refers to AWS A5.29/A5.29M:2005, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*, Clause 15.
[d] These filler metals are exempt from any measurement to determine hydrogen content.
[e] These optional tests may be used in lieu of the standard tests, at the option of the Contractor.

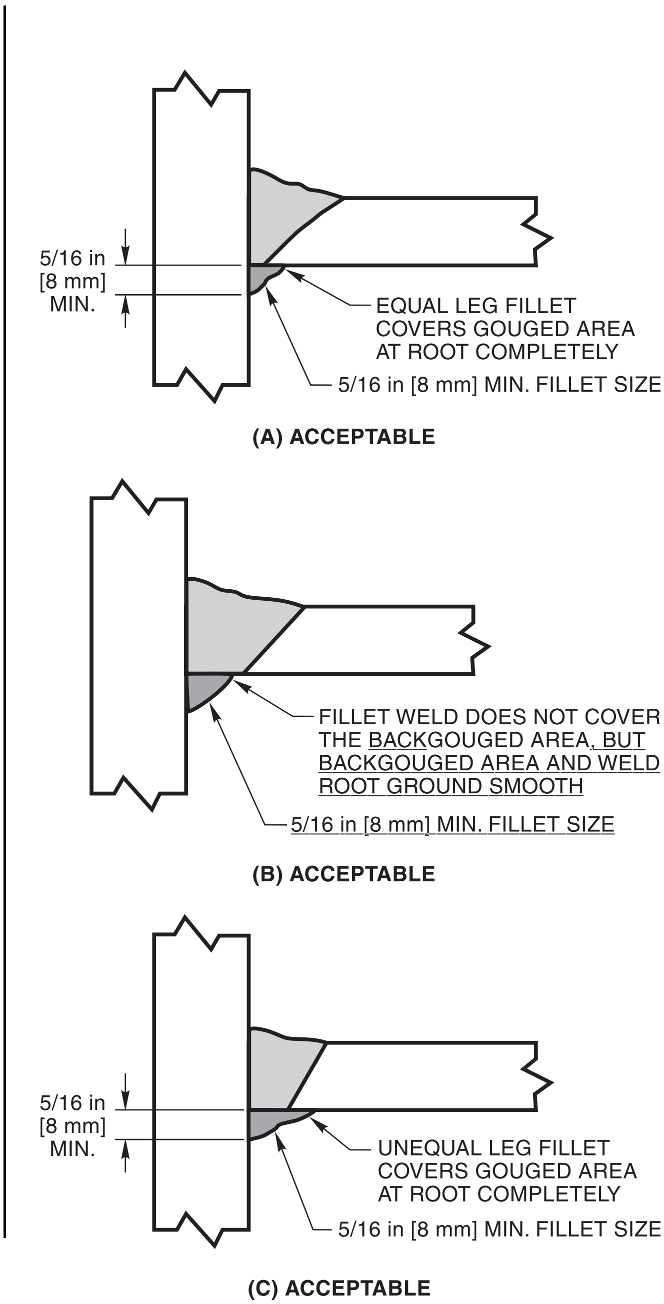
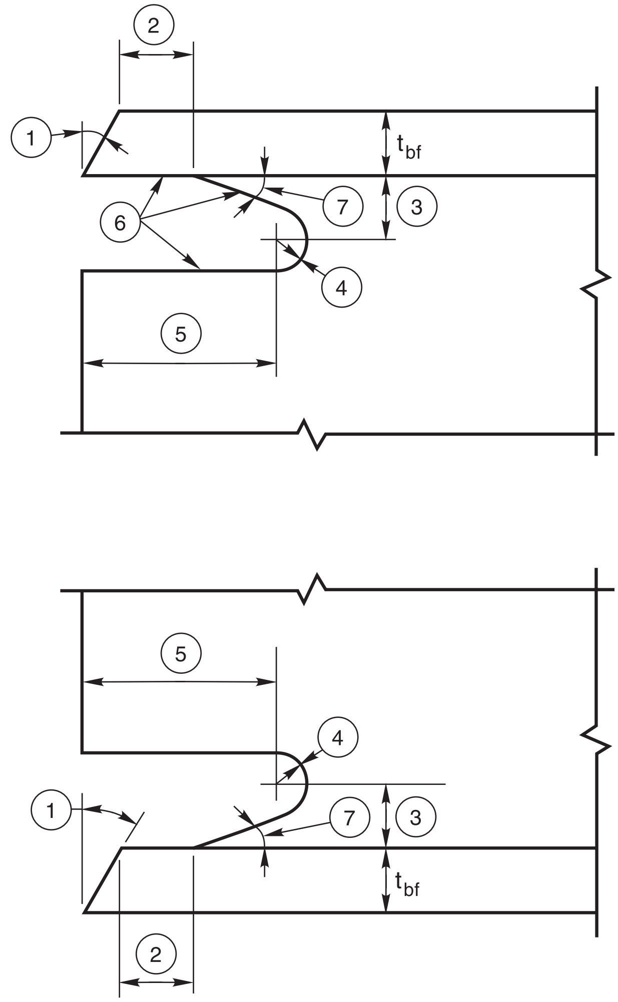
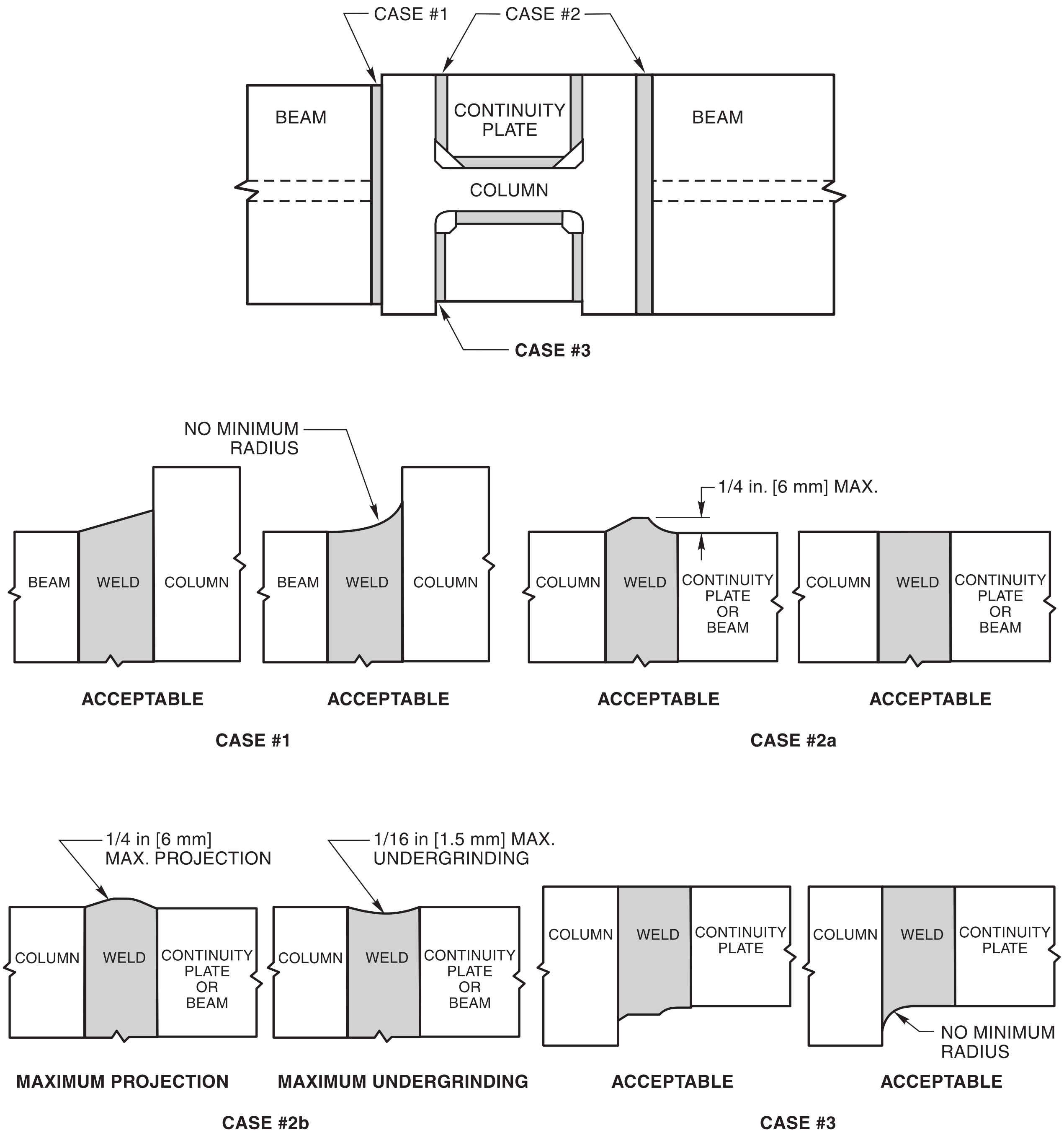


Figure 6.1—Reinforcing Fillet Requirements (see 6.8)



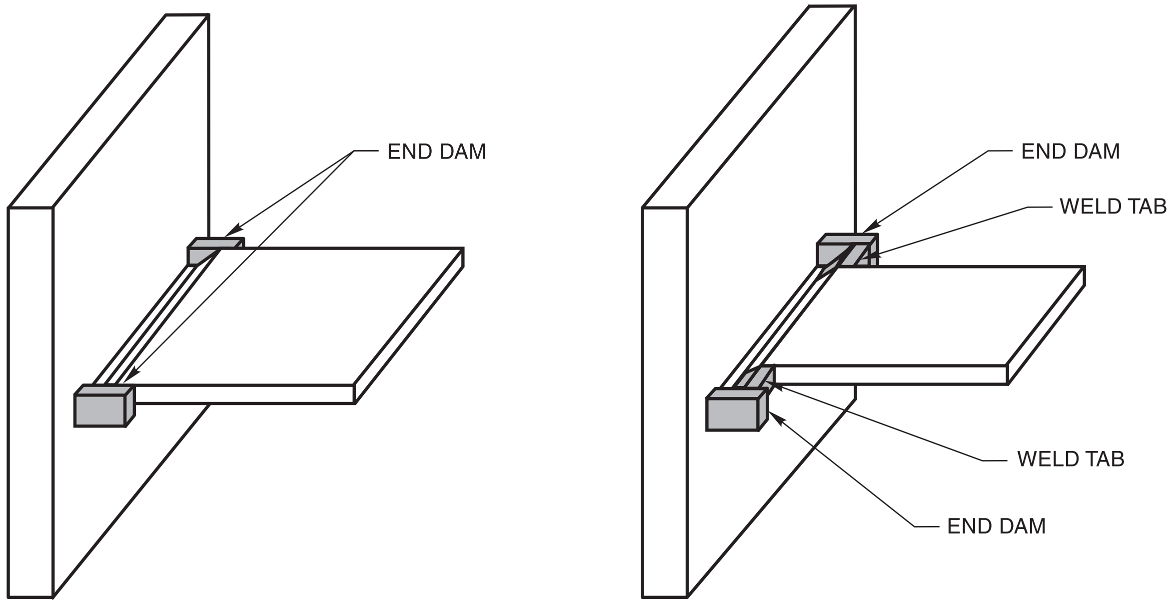
Notes:
1. Bevel as required for the WPS.
2. t_{bf} or 1/2 in [12 mm], whichever is larger (plus 1/2 t_{bf}, or minus 1/4 t_{bf}).
3. The minimum dimension shall be 3/4 t_{bf}, or 3/4 in [20 mm], whichever is greater. The maximum dimension shall be t_{bf} (+1/4 in [6 mm]).
4. 3/8 in [10 mm] minimum radius (–0, +unlimited).
5. 3 t_{bf} (±1/2 in [12 mm]).
6. See 6.10.2.1 for surface roughness requirements.
7. Tolerances shall not accumulate to the extent that the angle of the access hole cut to the flange surface exceeds 25°.

Figure 6.2—Alternate Geometry—Beam Flange Weld Access Hole Detail (see 6.10.1.2)



Note: All contours, thermal cuts exceeding 500 µin [13 µm] roughness shall be ground to 500 µin [13 µm] finish or smoother.

Figure 6.3—Acceptable Tab Removal Conditions (see 6.11.3)



(A) UNACCEPTABLE

(B) ACCEPTABLE
(provided the weld tabs are removed upon completion of the weld)

Figure 6.4—Acceptable and Unacceptable Use of End Dams (see 6.12.2)

7. Inspection

7.1 Inspection Task Assignment

When required by the Applicable Building Code or Contract Documents, the Engineer shall prepare a Quality Assurance Plan (QAP). The Quality Assurance Plan shall identify the specific Quality Control and Quality Assurance tasks to be performed on the project respectively by the Contractor and the Quality Assurance (QA) Agency. The Contractor and Quality Assurance Agency shall perform those tasks as identified in the Quality Assurance Plan.

7.2 Inspector Qualifications

7.2.1 QA Welding Inspector Qualifications. QA Welding Inspectors shall be qualified in accordance with one or more of the following:

(1) Welding Inspectors (WIs), or Senior Welding Inspectors (SWIs), as defined in AWS B5.1:2003, *Standard for the Qualification of Welding Inspectors*, except Associate Welding Inspectors (AWIs) may be used under the direct supervision of WIs, who are on site and available when weld inspection is being conducted, or

(2) Certified Welding Inspectors (CWIs), or Senior Certified Welding Inspectors (SCWIs) in accordance with the requirements of AWS QC1, *Standard for AWS Certification of Welding Inspector*, except Certified Associate Welding Inspectors (CAWIs) may be used under the direct supervision of CWIs, who are on site and available when weld inspection is being conducted.

(3) Level 2 Welding Inspectors or Level 3 Welding Inspectors, certified in accordance with the requirements of the Canadian Welding Bureau (CWB) in conformance with the Canadian Standard Association (CSA) Standard W178.2, *Certification of Welding Inspectors*, except Level 1 Welding Inspectors may be used under the direct supervision of Level 2 Welding Inspectors, who are on site and available when weld inspection is being conducted.

7.2.2 QA NDT Personnel Qualifications. Nondestructive testing personnel shall be qualified in accordance with their employer's written practice which shall meet or exceed the criteria of the American Society for Nondestructive Testing (ASNT) Recommended Practice SNT-TC-1A, *Recommended Practice for the Qualification and Certification of Nondestructive Testing Personnel*, or CP-189, *Standard for the Qualification and Certification of Nondestructive Testing Personnel*.

7.2.3 Quality Control (QC) Welding Inspector Qualifications. QC welding inspection personnel shall be Associate Welding Inspectors (AWI) or higher as defined in AWS B5.1:2003, or otherwise qualified under the provisions of AWS D1.1/D1.1M subclause 6.1.4, and to the satisfaction of the Contractor's QC program.

7.2.4 UT Technicians. Ultrasonic testing for QA shall be performed only by UT technicians:

(1) Certified as Level II or Level III by their employer, or

(2) Certified as ASNT Level III through examination by the ASNT.

Additionally, all UT technicians shall be certified by their employer as prescribed in Annex F for flaw detection.

7.3 Quality Assurance Agency Written Practice

The QA Agency shall perform work in accordance with a Written Practice. The Written Practice shall contain descriptions of the following:

(1) The training, experience, and examination required for qualification and certification of inspection personnel;

(2) Procedures for the selection and administration of inspection personnel;

(3) The Agency's inspection procedures, including general inspection, material controls, and visual welding inspection;

(4) The Agency's procedures for determining the acceptability of the structure in accordance with the applicable codes, standards, and specifications.

7.4 Wide-Flange k-Area Inspection

When required by the QAP, MT of the member web shall be performed after welding of doubler plates, continuity plates or stiffeners in the k-area. The member web area to be tested for cracks using MT shall include the k-area base metal within 3 in [75 mm] of the weld. The MT shall be performed no sooner than 48 hours following completion of the welding.

7.5 Lamellar Tearing

When required by the QAP, base metal shall be ultrasonically tested after welding for laminations and lamellar tearing. Any base metal discontinuities found within t/4 of the steel surface adjacent to the fusion line shall be accepted or rejected on the basis of criteria of AWS D1.1/D1.1M Table 6.2.

7.6 Beam Copes and Weld Access Holes

When required by the QAP, beam copes and weld access holes shall be inspected for cracks on the cut surface prior to welding. Inspection shall be performed using magnetic particle testing (MT) or dye penetrant testing (PT).

7.7 Repaired Weld Access Holes in the Protected Zone

Inspection of repairs to a weld access hole in the Protected Zone shall be by magnetic particle testing (MT) or dye penetrant testing (PT).

7.8 NDT of Repaired Tab Removal Sites

If a repair to a weld tab removal site is made by additional welding, magnetic particle testing (MT) shall be performed in the repaired area and area immediately adjacent to the repair.

7.9 MT Requirements

Magnetic particle testing shall be performed using the yoke method in accordance with written procedure that conforms to Annex G.

7.10 Ultrasonic Testing

7.10.1 Technique. Ultrasonic testing of welds required by the Quality Assurance Plan shall be performed according to the procedures prescribed in AWS D1.1/D1.1M Clause 6, Part F, following a written procedure containing the elements prescribed in Clause S3 of Annex S, UT Examination of Welds by Alternative Technique, of AWS D1.1/D1.1M. AWS D1.1/D1.1M Clause 6, Part F procedures shall be qualified using weld mockups having 1.5 mm diameter side drilled holes similar to Annex S Figure S.3 of AWS D1.1/D1.1M.

7.10.2 Acceptance Criteria—Flaw Detection. Acceptance criteria for CJP welds subjected to UT following the procedures contained in AWS D1.1/D1.1M Clause 6, Part F shall be in accordance with AWS D1.1/D1.1M Table 6.2. When the alternative procedures of AWS D1.1/D1.1M Annex S, UT Examination of Welds by Alternative Techniques, are approved by the Engineer for use, acceptance criteria shall be in accordance with AWS D1.1/D1.1M Table S.1, Weld Class S (statically loaded structures).

7.10.3 Unacceptable Welds. Welds that fail to meet the acceptance criteria prescribed in 7.10.2 shall be repaired. Alternatively, Flaw Sizing methods and acceptance criteria as prescribed in Annex H may be used with the Engineer's approval.

7.10.4 Left-in-Place Steel Backing. Joints shall not be rejected on the basis of the indication rating from geometric reflectors caused by left-in-place steel backing (see AWS D1.1/D1.1M subclause 6.26.12).

7.10.5 PJP Groove Welds. When UT of PJP groove welded joints is required, rejection shall not be on the basis of the indication rating from the root area of the weld.

Annex A (Normative)

WPS Heat Input Envelope Testing of Filler Metals for Demand Critical Welds

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

A1. Purpose

This annex provides testing procedures used to determine the suitability of filler metals to be used in producing Demand Critical welds in accordance with this code. These procedures are intended to assure that welds deposited with filler metals tested in accordance with these procedures will be capable of providing welded joints with the required strength, ductility, and notch toughness at the anticipated service temperatures, for the range of heat input rates that may be experienced under the production WPS.

A2. Testing Procedure

Two test plates shall be used. One test plate ("high heat input test") shall be welded using a computed heat input level no less than the maximum level that will be used in production. A second test plate ("low heat input test") shall be welded using a computed heat input level no greater than the minimum level that will be used in production. Table A. 1 provides suggested high and low heat input limits. Heat input tests may be performed at higher or lower levels of heat input than those provided for in Table A.1.

A3. Preheat and Interpass Temperature

The preheat and interpass temperatures of Table A.1 shall apply to all low and high heat input testing.

A4. Test Plate Details

Two test plates shall be required, one for each heat input level. The test plate shall be as shown in Figure A.1. Plates for qualification of E70 filler metals shall conform either to ASTM A 36, A 572 Grade 50, or A 992. Plates for qualification of E80 filler metals shall conform to either ASTM A 36, A 572 Grade 50, ASTM A 572 Grade 65, or A 913 Grade 65, at the Contractor's option. Steel backing shall be of one of the five specifications and grades listed above, but need not be the same as the base material used for the qualification test plates.

A5. Welding of Test Plate

The Heat Envelope Test Plate shall be prepared as prescribed in Figure A.1.

A5.1 Preheat and Interpass Temperature. The test assembly shall be heated, when required, to the specified preheat temperature, measured at a location 1 in [25 mm] from the center of the groove at the location shown in Figure A.1. The interpass temperature shall be measured before each weld pass is made. When the maximum interpass temperature prescribed in Table A.1 is exceeded, the test plate shall be allowed to cool until the prescribed temperature is achieved. The interpass temperature shall be maintained for the remainder of the welding. Should it be necessary to interrupt welding, the assembly shall be heated, if necessary, to the prescribed interpass temperature before welding is resumed.

A5.2 Heat Input. The test plate shall be welded with a combination of variables that will generate the desired high or low level of heat input. The test plate shall be completed such that the computed heat input value for each weld pass does not vary from the desired heat input level by more than ±20%.

A5.3 Warpage. A completed test plate that is warped more than 5° from flat shall be discarded. Welded test assemblies shall not be straightened.

A5.4 Thermal Treatment. No thermal treatment of weldment or test specimens is permitted, except that machined tensile test specimens may be aged at 200°F to 220°F [95°C to 105°C] for up to 48 hours, then cooled to room temperature, before testing.

A6. Test Specimens Required

The test specimens shall be as shown in Figure A.1. Test specimens shall include, for each test plate, five CVN test specimens and one all-weld-metal tensile specimen. All test specimens shall be taken near the centerline of the weld at the mid-thickness location, in order to minimize dilution effects. Specimens shall be prepared in accordance with the latest edition of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

A7. Acceptance Criteria

A7.1 Strength and Ductility Requirements. The all-weld-metal tensile test specimens shall meet strength and ductility requirements as prescribed in Table A.2, as applicable.

A7.2 CVN Toughness Requirements. The lowest and highest values obtained from the five test specimens from each test plate shall be disregarded. Two of the remaining three values shall equal or exceed the specified CVN toughness of 40 ft·lbf [54 J] energy level at the testing temperature. One of the three may be lower, but not lower than 30 ft·lbf [40 J]. The average of the three shall not be less than the requirements of Table A.2.

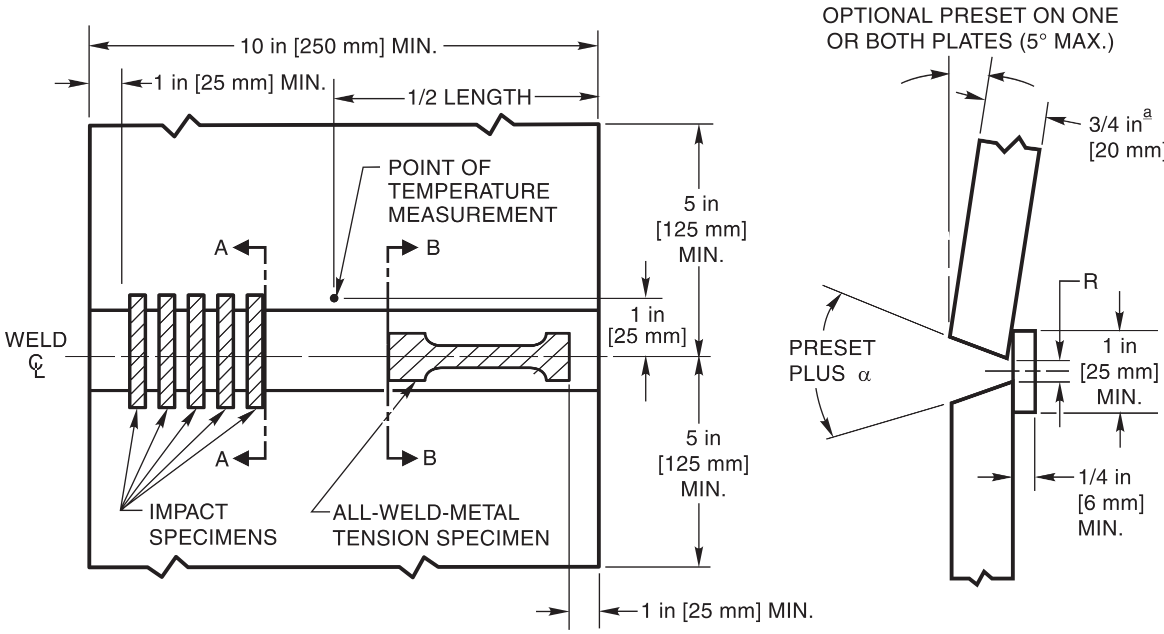
Table A.1
Heat Input Envelope Testing—Heat Input, Preheat, and Interpass Temperatures

	Suggested Heat Input	Maximum Preheat Temperature	Maximum Interpass Temperature
Low Heat Input Test	30 kJ/in [1.2 kJ/mm]	120°F [40°C]	250°F [120°C]
	Suggested Heat Input	Minimum Preheat Temperature[a]	Minimum Interpass Temperature[a]
High Heat Input Test	80 kJ/in [3.1 kJ/mm]	250°F [120°C]	450°F [240°C]

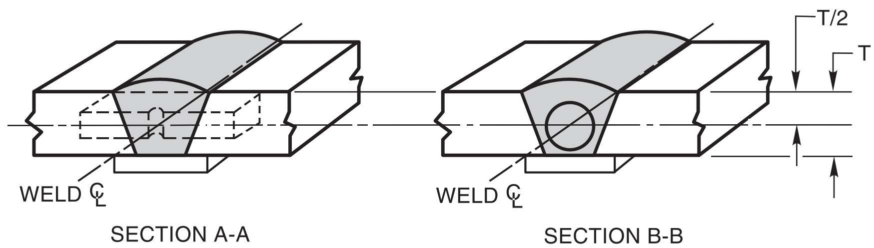
[a] For the high heat input test, the test plate shall be heated to the minimum preheat, and then welding shall begin. Welding shall continue without substantial, deliberate interruption until the minimum interpass temperature is obtained. After the test plate has been heated to the minimum interpass temperature, all subsequent weld passes shall be made at a temperature not less than the minimum interpass temperature. Should the test plate temperature fall below the minimum interpass temperature for any reason, the test plate shall be heated to a temperature not less than the minimum interpass temperature before welding resumes. If the required interpass temperature is not achieved prior to interruption of the welding operations, welding shall not resume until the test assembly has been heated to the prescribed minimum interpass temperature.

Table A.2
All Weld Metal Mechanical Properties; Yield Strength, Tensile Strength, Elongation, and CVN Toughness Requirements (see A7.1, A7.2)

Nominal Electrode Classification Strength	E70	E80
Minimum Yield Strength, ksi [MPa]	58 [400] min.	68 [470] min.
Minimum Tensile Strength, ksi [MPa]	70 [480] min.	80 [550] min.
Minimum Elongation (%), measured in a 2 in [50 mm] gage length	22 min.	19 min.
Minimum CVN Toughness when LAST is greater than or equal to +50°F [10°C]	40 ft·lbf [54 J] @ +70°F [21°C]	40 ft·lbf [54 J] @ +70°F [21°C]
Minimum CVN Toughness when LAST is less than +50°F [10°C]	40 ft·lbf [54 J] @ LAST + 20°F [10°C]	40 ft·lbf [54 J] @ LAST + 20°F [10°C]



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) ORIENTATION OF IMPACT SPECIMEN **(C) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN**

	Root Opening (R)	Groove Angle (α)
OPTION 1	1/2 in [12 mm]	45°
OPTION 2	5/8 in [16 mm]	20°

[a] For SAW, test plate thickness may be 1 in [25 mm].

Figure A.1—Heat Input Envelope Test Plate (see A4, A5.1, A6)

Annex B (Normative)

Intermix CVN Testing of Filler Metal Combinations (where one of the filler metals is FCAW-S)

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

B1. Purpose

This annex provides testing procedures used to determine the suitability of combining FCAW-S with other welding processes in a single joint. The testing as required by this annex may be performed by the filler metal manufacturer, the Contractor, or an independent testing agency.

B2. Filler Metal Variables

Filler metal essential variables for the intermix CVN testing shall be as summarized in Tables B.1 and B.2. Changes in these essential variables shall require an additional test.

B3. Test Plate Details

A single test plate of ASTM A 36, A 572 Grade 50, or A 992 shall be used to evaluate E70 filler metal combinations, and ASTM A 572 Grade 65 or A 913 Grade 65 shall be used to evaluate E80 filler metal combinations. The test plate shall be 3/4 in [20 mm] thick, with either a 5/8 in [16 mm] root opening with a 20° included groove angle, or a 1/2 in [12 mm] root opening with a 45° included groove angle. The test plate and specimens shall be as shown in Figure B.1. Alternatively, a PQR test plate may be used in accordance with 6.3.4(2).

B4. Welding of Test Plate

The sequence of placement of weld metals shall be the same as that to be employed in production. The first material shall be known as the substrate/root material, and the subsequent material shall be known as the fill material. Approximately one-third the thickness of the test joint shall be welded with the substrate/root material. The balance of the joint shall be welded with the fill material.

B5. Test Specimens Required

Five or ten CVN test specimens shall be made from the test plate, depending on the required number of tests. CVN specimens shall be prepared in accordance with AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, Clause A3.

B6. CVN Specimen Location

The CVN impact bar shall be located as follows:

(1) Transverse specimens from which CVN bars are to be machined shall be etched to reveal the cross section of the weld.

(2) A line shall be scribed on the etched cross section, at the interface of the two welding process deposits (see Figure B.2).

(3) The CVN specimen shall be taken from primarily material deposited by the second process. The interface location shall be included in the specimen, with the edge of the specimen within 1/16 in [1.5 mm] of the interface location (see Figure B.3).

B7. Acceptance Criteria—All Welds

For all welds governed by this code, the required CVN toughness value shall be 20 ft·lbs [27 J] at 0°F [–18°C]. The lowest and highest values obtained from the five test specimens shall be disregarded. Two of the remaining three values shall equal or exceed 20 ft·lbs [27 J] at the testing temperature. One of the three may be lower, but not lower than 15 ft·lbs [20 J] at 0°F [–18°C]. The average of the three shall not be less than 20 ft·lbs [27 J].

B8. Acceptance Criteria—Demand Critical Welds

For Demand Critical welds, in addition to the criteria of B7, the required notch toughness value shall be 40 ft·lbs [54 J] at 70°F [20°C], or at the temperature as required by 6.3.6. The lowest and highest values obtained from the five test specimens shall be disregarded. Two of the remaining three values shall equal or exceed 40 ft·lbs [54 J] at the testing temperature. One of the three may be lower, but not lower than 30 ft·lbs [40 J] at the testing temperature. The average of the three shall not be less than 40 ft·lbs [54 J]. For applications where LAST is below +50°F [+10°C], the CVN testing temperature shall be LAST plus 20°F [10°C].

Table B.1
Filler Metal Essential Variables—FCAW-S Substrate/Root

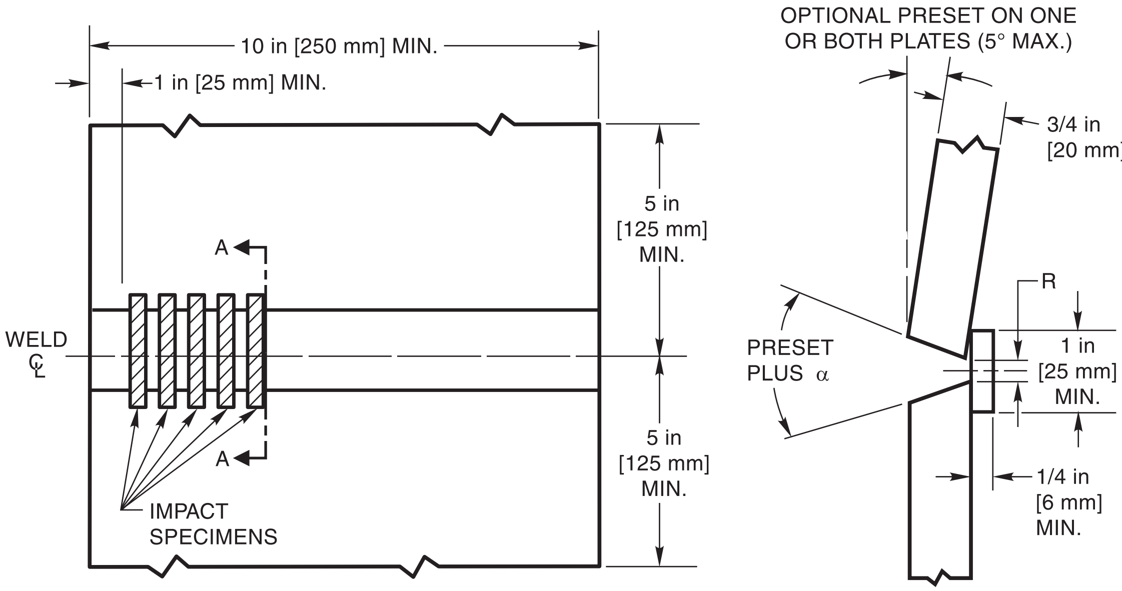
	Substrate/Root	Fill					
	FCAW-S	FCAW-S	FCAW-G	SMAW	GMAW	SAW	Other
AWS Classification	X		X	X	X	X	X
Manufacturer	X		X	X		X	X
Manufacturer's Brand and Trade Name	X		X	X		X	X
Diameter			X	X	X	X	X

Note: An "X" in the column indicates that the essential variable is applicable for the particular welding process and weld type.

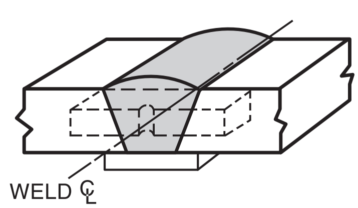
Table B.2
Filler Metal Essential Variables—FCAW-S Fill

	Substrate/Root						Fill
	FCAW-S	FCAW-G	SMAW	GMAW	SAW	Other	FCAW-S
AWS Classification		X	X	X	X	X	X
Manufacturer		X	X		X	X	X
Manufacturer's Brand and Trade Name		X	X		X	X	X
Diameter							X

Note: An "X" in the column indicates that the essential variable is applicable for the particular welding process and weld type.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



SECTION A-A

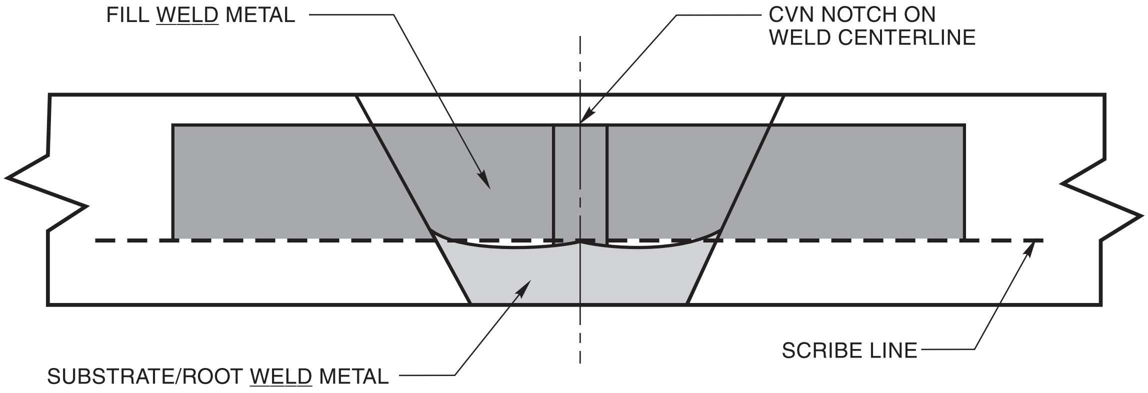
(B) ORIENTATION OF IMPACT SPECIMEN

Note: See Figures B.2 and B.3 for positioning of CVN specimen.

	Root Opening (R)	Groove Angle (α)
OPTION 1	1/2 in [12 mm]	45°
OPTION 2	5/8 in [16 mm]	20°

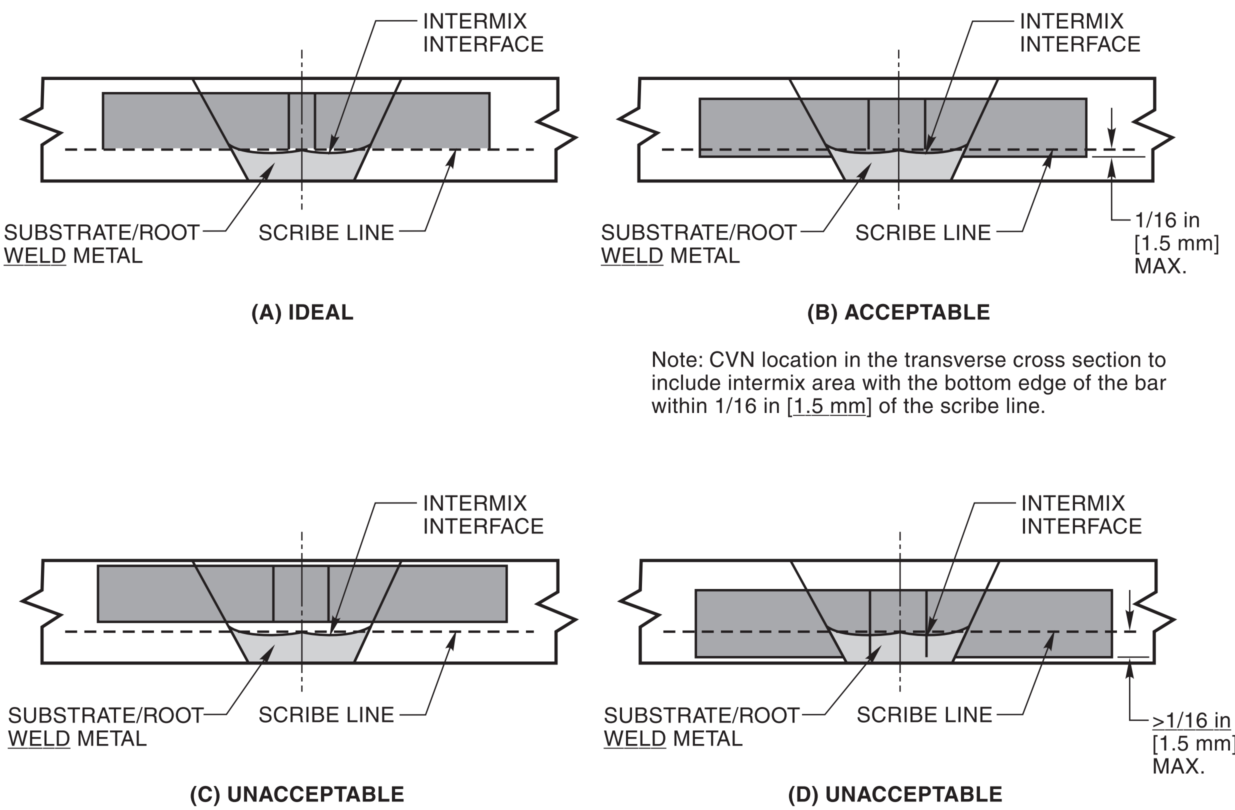
Note: CVN specimen edge to be adjacent to intermix scribe line (see Figure B.3).

Figure B.1—Intermix Test Plate (see B3)



Note: CVN specimen edge is on scribe line.

Figure B.2—Interface Scribe Line Location [see B6(2)]



Note: CVN location in the transverse cross section to include intermix area with the bottom edge of the bar within 1/16 in [1.5 mm] of the scribe line.

Figure B.3—Intermix CVN Test Specimen Location [see B6(3)]

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Annex C

There is no Annex C. Annex C has been omitted in order to avoid potential confusion with references to Commentary clauses.

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Annex D (Normative)

Supplemental Welder Qualification for Restricted Access Welding

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

D1. Purpose

This annex provides supplemental welder qualification testing procedures for welders who will perform production welding on Demand Critical beam bottom flange to column joints, where such welds must be performed by welding through a weld access hole. Welders previously qualified using similar restricted access plate tests, prior to adoption of this code, shall be deemed qualified under these provisions for the duration of their qualification period.

D2. Test Plate Configuration

The test plate configurations and dimensions shall be as shown in Figure D.1 or Figure D.2 as applicable, and Figure D.3.

D3. Test Plate Fabrication

D3.1 General Requirements

D3.1.1 Test Plate Assembly. The parts for the test plate assembly may be cut and tack welded together by an individual other than the welder performing the qualification test, except that the welder being qualified shall attach the required weld tabs. The weld tabs shall be attached in accordance with 6.11.2, and shall conform to 6.11.1.

D3.1.2 Welding Procedure Specification. The test plate assembly shall be welded in accordance with a WPS using the process for which the welder is being qualified. The combination of variables shall be such that the deposition rate used in the qualification test is equal to or greater than the highest deposition rate that will be used in production.

D3.1.3 Weld Passes and Interpass Requirements. The welder shall make all weld passes required to complete the assembly, and shall clean his or her own welds. The welder shall measure the interpass temperature to ensure compliance with the WPS.

D3.1.4 Test Specimen Preparation. The location of the web plate shall be clearly identified on the test plate so that, when the web plate is removed, the previous orientation and location of the web plate will be discernible on the test plate. The test assembly may be cut apart by an individual other than the welder being qualified.

D3.2 Option A. Option A shall be used to qualify welders when the production WPS specifies the use of steel backing.

D3.2.1 Steel Backing. The steel backing shall be a minimum thickness of 1/4 in [6 mm], and a maximum of 3/4 in [20 mm], and shall be at least 1 in [25 mm] wide. The backing shall be attached to the test plate assembly with tack welds in accordance with 6.6.

D3.2.2 Groove Weld Detail. The groove weld detail shall use a 3/8 in [10 mm] root opening, ±1/16 in [1.5 mm]. The included angle shall be 30°, ± 5°.

D3.2.3 Optional Backing Removal. Removal of the steel backing from the test assembly is not required. At the Contractor's option, steel backing may be removed. If steel backing is removed from the test assembly, the backing shall be removed by the welder being qualified. Backing removal shall be done in the overhead position.

D3.2.4 Backgouging and Backwelding. If the steel backing is removed from the Supplemental Welder Qualification for Restricted Access Welding—Option A test plate assembly, the weld root shall be backgouged and backwelded in the overhead position by the welder being qualified. The depth of backgouging shall not exceed 1/4 in [6 mm]. The welding process for the overhead welding need not be the same as that used for the flat position welding, and need not be the same as will be used in production.

D3.2.5 Option A Limitations. Welders qualified in accordance to Option A shall be permitted to weld on any joint that uses steel backing, providing that the same welding process is used for the flat position welding, and providing that the deposition rate does not exceed the rate used in the qualification test. Separate welder qualification with an Option B test plate shall be required if the type of backing is changed (e.g., a change from steel to ceramic, or from steel backing to open root joints, etc.).

D3.3 Option B. Option B shall be used to qualify welders when the production WPS specifies the use of other than steel backing, including the use of ceramic or copper backing, or open root welding.

D3.3.1 Backing, Root Condition, and Groove Weld Details. The backing and/or root condition shall be as specified in the WPS. The groove weld details shall be as specified in the WPS.

D3.3.2 Backing Removal. After the groove weld has been completed, the nonsteel backing (if used) shall be removed by the welder being qualified. The root of the weld shall be treated as required by the WPS.

D3.3.3 Backgouging and Backwelding. After the nonsteel backing is removed from the Supplemental Welder Qualification for Restricted Access Welding—Option B test plate assembly, the weld root may be backgouged and backwelded. The depth of backgouging shall not exceed 1/4 in [6 mm]. When the weld root is backgouged and backwelded, such operations shall be done in the overhead position by the welder being qualified. The welding process for the overhead welding need not be the same as that used for the flat position welding, and need not be the same as will be used in production.

D3.3.4 Option B Limitations. Welders qualified in accordance to Option B shall be qualified to use the specific backing type listed on the WPS. Joint details may vary from the WPS values used for the welder qualification test as follows:

(1) Root openings shall be no greater than that used in the welder qualification test.

(2) Groove angles shall be no less than that used in the welder qualification test.

Separate qualification shall be required if the type of backing is changed (e.g., a change from copper to ceramic, or copper to steel, etc.).

D4. Specimen Testing

D4.1 Visual Inspection. After removal of the web plate, column plate, and attachment plate, the weldment shall be visually inspected. The weld shall be inspected in accordance with AWS D1.1/D1.1M subclause 4.8.1. No weld repairs to the test plate shall be permitted once it has been submitted for evaluation.

D4.2 Additional Testing. The test plate shall be subject to one of the following tests, at the option of the Contractor:

(1) Bend tests (see D4.2.1)

(2) RT inspection (see D4.2.2)

(3) UT inspection (see D4.2.3)

If the left-in-place backing interferes with the testing method being used, it may be removed by anyone. When this is done, it shall be removed in such a manner that no further welding is required before testing.

D4.2.1 Bend Tests

D4.2.1.1 Specimen Locations. The flat test plate shall be cut to prepare four transverse side-bend tests, with each test sample 3/8 in [10 mm] thick. Two side-bend specimens shall be from the region that was under the 1 in [25 mm] web plate. Two side bends shall be taken from within 1/4 in [6 mm] of the ends of the welds. The side of the specimen nearest to the end of the weld shall be clearly marked (see Figure D.4).

D4.2.1.2 Specimen Testing Procedure. Testing of the side bends shall be done in accordance with AWS D1.1/D1.1M subclause 4.8.3.1. For the two specimens taken from the ends of the weld, the specimens shall be bent so that the side of the bend specimen that was nearest to the end of the weld becomes the convex side of the bend specimen (e.g., is subject to the greatest tension). Bend specimens may be artificially aged in accordance with AWS D1.1/D1.1M subclause 4.2.2.

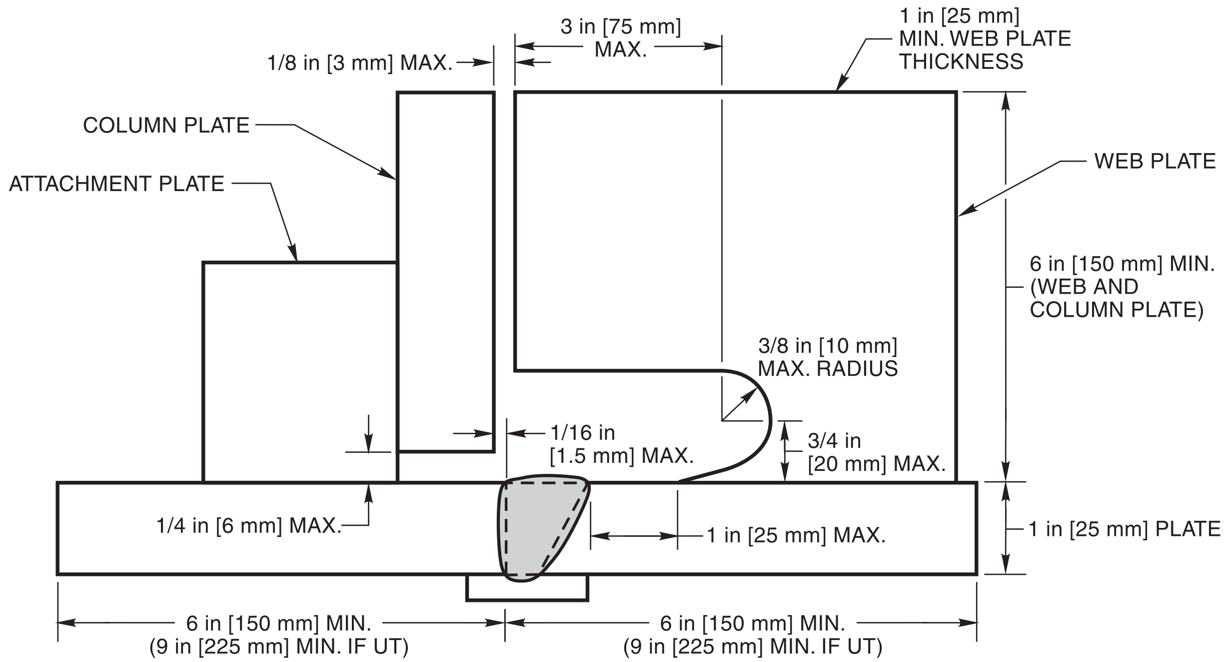
D4.2.1.3 Acceptance Criteria. Acceptance criteria for all specimens shall be in accordance with AWS D1.1/D1.1M subclause 4.8.3.3.

D4.2.2 RT Inspection. The full length of the test plate shall be inspected. Testing shall be done in accordance with AWS D1.1/D1.1M subclause 4.30.3. Edge blocks shall be required.

D4.2.3 UT Inspection. The full length of the test plate shall be inspected. Inspection shall be done in accordance with AWS D1.1/D1.1M subclause 6.13.2. Testing shall be performed from both the A and B face, and sides 1 and 2.

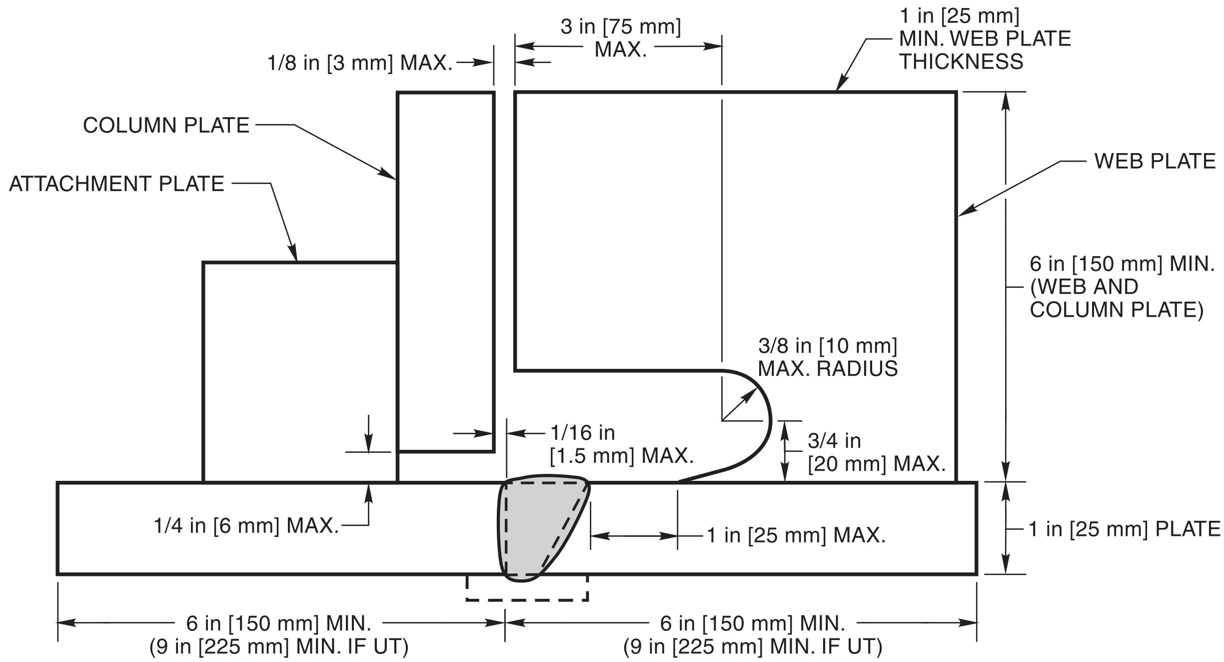
D5. Retesting

If the welder fails to pass the qualification tests prescribed in this annex, the welder may perform an additional test. If the welder fails a second test, the welder shall be not be permitted to retest until the welder has received sufficient additional training and practice.



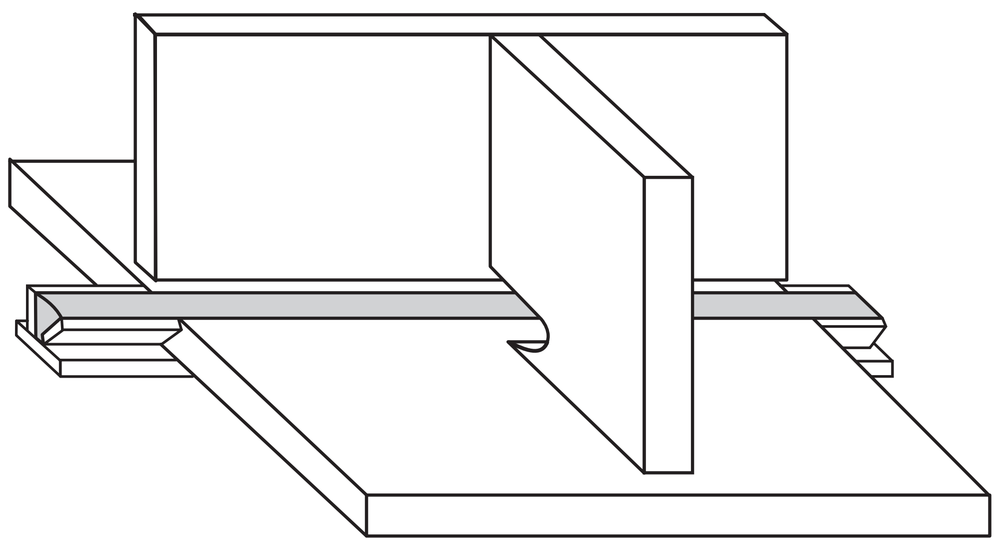
Notes:
1. The weld access hole dimensions are applicable for this test only.
2. Groove dimensions shall be 3/8 in [10 mm] root opening (±1/16 in [1.5 mm]) and 30° bevel (±5°).
3. Backing shall be equal to or greater than 1/4 in [6 mm] but not greater than 3/4 in [20 mm] thick, and shall be a minimum of 1 in [25 mm] wide. The length of the backing shall be 12 in [300 mm], plus run off length, min.
4. The test plates and column plate shall be same length, 12 in [300 mm] min.
5. The attachment plate may be of any size and dimension.
6. The column plate may be any thickness.

Figure D.1—Test Plate Configuration for Option A (see D2)



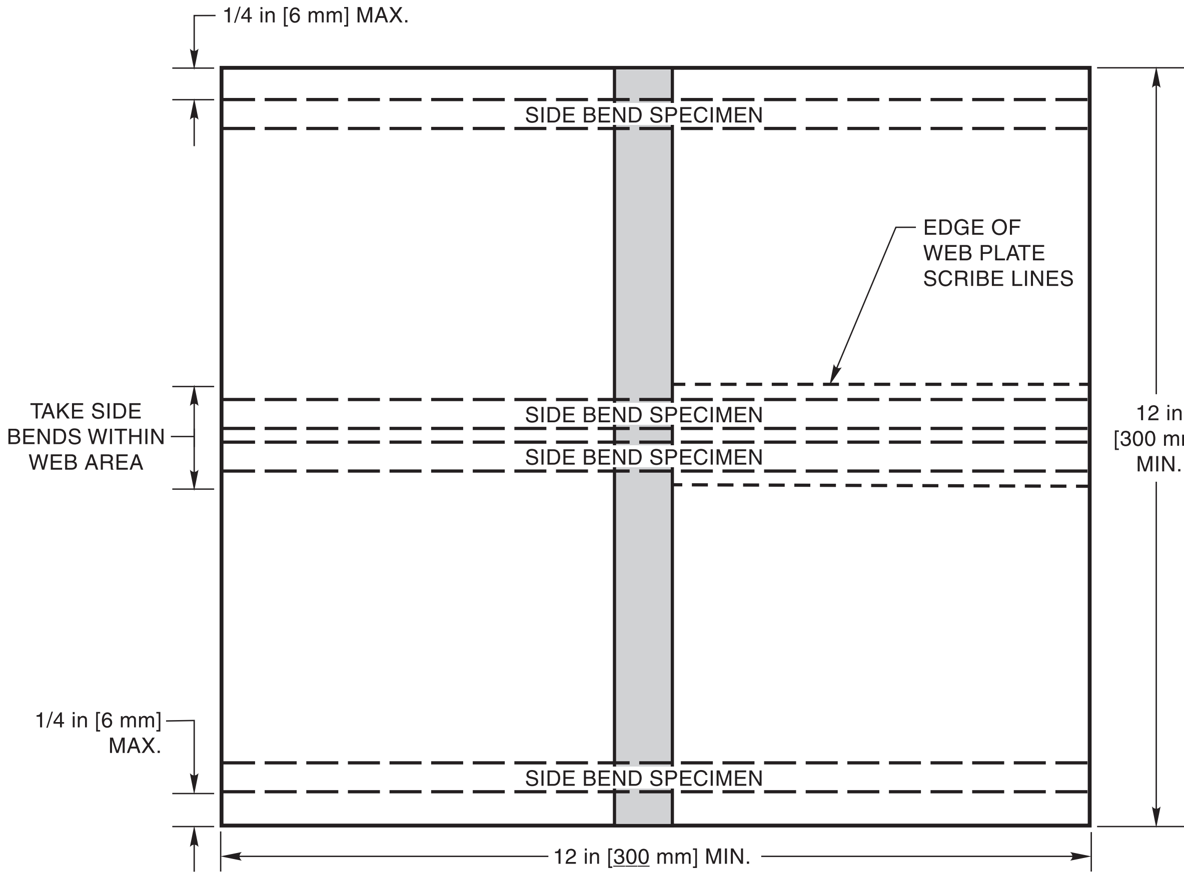
Notes:
1. The weld access hole dimensions are applicable for this test only.
2. Nonsteel backing type shall be as specified in WPS or shall be open root.
3. All groove dimensions shall be as specified in the WPS.
4. The test plates and column plate shall be same length, 12 in [300 mm] min.
5. The attachment plate may be of any size and dimension.
6. The column plate may be any thickness.

Figure D.2—Test Plate Configuration for Option B (see D2)



Notes:
1. The web location shall be marked on the test plates prior to disassembling the test configuration (see D3.1.4).
2. The web plate shall be centered on the test plate.

Figure D.3—Test Plate Configuration Illustration (see D2)



Notes:
1. See Annex D1, Figure D.1, and Figure D.2 for test assembly, groove detail, and test procedure requirements.
2. Test plates shall be a minimum of 1 in [25 mm] thick.
3. The web plate thickness area shall be 1 in [25 mm] thick. The web area shall be clearly marked on the plates before removal. Two side bend specimens shall be taken from within the web area; the entire width of each specimen shall be within the web area.
4. Side bends shall be 3/8 in [10 mm] thick. Testing shall be done in accordance with AWS D1.1/D1.1M subclause 4.8.3.1.
5. The two bend specimens taken near the ends of the welds shall be bent so that the side of the bend specimen that was nearest to the end of the weld becomes the convex side (sees the greatest tension).

Figure D.4—Location of Side Bend Specimens on Test Plates— Supplemental Welder Qualification (see D4.2.1.1)

Annex E (Normative)

Supplemental Testing for Extended Exposure Limits for FCAW Filler Metals

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

E1. Purpose

The supplemental testing prescribed in this annex shall be used when exposure periods in excess of 72 hours as permitted by 6.4.3(3) are to be utilized for FCAW electrodes.

E2. Test Exposure Conditions

The electrode shall be exposed to an environment of 80°F (+5°F, –0°F) [27°C (+3°C, –0°C)] and 80% (+5%, –0%) relative humidity for the period of time desired to be approved for accumulated exposure. The environmental chamber shall meet the requirements of AWS A5.5/A5.5M:2006 subclause 16.4, except for subclause 16.4(3). Exposure time shall begin when the environmental chamber has reached the required temperature and humidity. Time, temperature, and humidity shall be continuously recorded for the period that the electrodes are in the chamber.

E3. Diffusible Hydrogen Testing

E3.1 Electrode Conditioning Prior to Testing. No conditioning of electrode after exposure and prior to testing shall be permitted.

E3.2 Testing Procedures. Testing for diffusible hydrogen levels shall be performed in accordance with AWS A5.20/A5.20M:2005 Clause 16, Diffusible Hydrogen Test, except the electrode diameter shall be in accordance with one of the following options:

(1) Tests are performed with electrodes a diameter larger and a diameter smaller than that used in production.

(2) Tests are performed using the diameter of electrode to be used in production.

The electrodes shall be exposed to the environment as specified in Clause E2. The A5.20/A5.20M:2005 provisions for "previously unopened containers" and for "as received condition" shall not apply. The exposure conditions and period shall be stated on the test report.

E4. Exposure Limitation Criteria

E4.1 Qualification of Alternate Atmospheric Exposure Criteria. The electrode shall be approved for accumulated atmospheric exposure longer than the default exposure time period of 72 hours provided the electrode, as tested in accordance with AWS A4.3, modified by the above restrictions, satisfies the maximum diffusible hydrogen requirements for H16 or less.

E4.2 Storage and Atmospheric Exposure. Based upon test results, the manufacturer of the electrode, or a consultant approved by the Engineer for this purpose, shall provide recommendations for storage and atmospheric exposure to ensure that the diffusible hydrogen level will not exceed H16. Such recommendations may take the form of fixed exposure periods, or specific exposure limits based upon different temperature and humidity conditions.

E4.3 Heating, Baking, and Rebaking. Provisions may also include requirements for heated storage and/or baking of electrode wires. Rebaking of wire shall be included only when approved by the electrode manufacturer and documented by testing that, after the baking procedure, the wire has returned to a diffusible hydrogen of H16 or better.

Annex F (Normative)

Supplemental Ultrasonic Technician Testing

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

F1. Personnel

Ultrasonic testing (UT) personnel shall demonstrate proficiency by satisfactory performance in a qualification examination as prescribed below.

F2. Examination

The examination shall consist of practical tests that have been developed by the NDT Agency's UT Level III, or an organization approved by the Agency, and shall incorporate the specific requirements of the NDT Agency's procedures and the applicable weld quality acceptance standards contained in 7.10.2. The examination shall utilize the UT procedure(s) of AWS D1.1/D1.1M Clause 6, Part F for Flaw Detection. Alternatively, when AWS D1.1/D1.1M Annex S is to be used, the examination shall utilize the UT techniques of Annex S, UT Techniques for Flaw Detection.

In addition to the above requirements, the examination shall also test the ability of UT personnel to correctly calibrate UT equipment and complete the relevant paperwork associated with the examination. Testing procedures and examination results shall be documented and available to the Engineer for review.

F3. Test Specimens

F3.1 Geometry. The test specimens shall be representative of the details of typical welded joints, but need not duplicate the exact conditions (thickness, width, skew, root opening, groove angle, grade of steel, etc.) that will be used on the actual project. The specimens shall be mockups of welded joints, with and without steel backing. Typical joint geometry using butt and tee configurations shall be utilized.

F3.2 Material Imperfections. All test specimen materials shall be examined by longitudinal wave techniques to identify the presence or absence of laminations and/or inclusions. Materials containing detected laminations shall not be used for test specimens where the laminations would preclude accurate weld testing. Materials containing these planar anomalies may be intentionally incorporated into selected coupons to evaluate the candidate's performance on these imperfections.

F3.3 Discontinuities (Natural and Artificial). Test coupons shall contain natural discontinuities and/or artificial reflectors consisting of nonmetallic inserts in the weld deposit, or thin steel inserts fillet welded to bevel preparations to simulate incomplete fusion. The size of discontinuities inserted or induced into the test coupons shall be consistent with the range of flaw size acceptance criteria set forth in this document.

F3.4 Confirmation and Categorization of Flaws. After fabrication, test specimens shall be examined by RT or UT to confirm the location and size of flaws. Two UT Level III Technicians shall agree that each reflector in the test plates is properly categorized as defined herein.

F3.5 Number of Flaws. At least 20 flaws shall be used for the examination of each technician.

F3.6 Test Specimen Confidentiality. Information regarding the discontinuities used for an examination shall not be discussed with the candidate prior to or following completion of the examination, if the test pieces are to be used for later examinations.

F3.7 Number of Test Plates. The 20 flaws shall be distributed over multiple test plates.

F4. Candidate Scoring for Flaw Detection

This shall apply for AWS D1.1/D1.1M Clause 6, Part F and for Annex S, UT Techniques for Flaw Detection.

F4.1 Candidate Test Report. UT candidates shall submit a written report of all detected discontinuities found during the test piece examination. The report shall include each detected flaw, indication rating (decibels), size (length), location along the weld, and position within the weld cross section.

F4.2 Scoring Methodology and Formulas. An indication shall be considered a "detected flaw" if at least two of the following attributes are correctly identified within the listed tolerances:

(1) Indication Rating within ±6 dB

(2) Indication Length within +1 in to –0.5 in [+25 mm to –12 mm]

(3) Indication Depth within ±0.25 in [±6 mm]

An indication shall be considered a "false indication" if the flaw does not exist, but is reported.

The rate of flaws detected, based upon reporting of the flaw and its location, is:

D = detected flaws/total flaws

The rate of false indications, is:

F = false indications/total indications

The UT technician rating is:

R = 1/2 (1 + D – F)

To be qualified to perform flaw detection, the candidate shall achieve all of the following:

(1) An overall rating R of 0.90 or higher

(2) A detection rating D of 0.87 or higher

(3) A false indication rating F of 0.15 or less

F5. Period of Effectiveness

Previously qualified personnel shall be requalified when they have not performed UT of steel construction for a period of 6 months or more.

Annex G (Normative)

Supplemental Magnetic Particle Testing Procedures

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

G1. Purpose

The purpose of this annex is to improve the reliability of Magnetic Particle Testing (MT) to locate any surface breaking flaws such as cracks and incomplete fusion that should be readily detectable with the yoke method.

G2. Procedure Qualification

Written MT examination procedures shall be prepared, considering the geometry of the work to be inspected, yoke application, light levels, accessibility, safety, and other factors.

The following items shall be detailed in the written procedure:

(1) Type of weld to be examined

(2) Type of magnetizing equipment, including type of current employed

(3) Surface preparation

(4) Examination sequence

(5) Magnetization plan

(6) Magnetic particle type and color

(7) Interpretation of indications

(8) Acceptance criteria

(9) Reporting forms and procedures

G3. Visual Inspection

Prior to MT, the weld shall be inspected visually for detection of imperfections. The inspected surface shall surface be cleaned where necessary.

G4. Surface Condition

The surface shall be cleaned prior to MT by grinding, wire brushing, hand scraping, or a combination of these. Welds shall be dry and free from foreign materials such as dirt, grease, rust, and excessive weld spatter.

G5. Method

The continuous method, using an AC or DC electromagnetic yoke (double-leg or single-leg configuration) with dry, white-light-visible magnetic particles, shall be used.

G6. Yoke

The yoke shall be of the articulating-leg type. A single-leg yoke may be used in areas of tight access. Fixed-leg yokes are not permitted. AC yokes shall have a lifting force of at least 10 lbs [4.5 kg] and DC yokes shall have a minimum lifting force of at least 40 lbs [18 kg] when the legs are spaced at the maximum inspection distance.

G7. Magnetization

A magnetizing current at 50 Hz to 60 Hz AC or DC electromagnetization shall be used for detection of surface-breaking discontinuities.

G8. Particles

The magnetic particles shall be dry, finely divided high-permeability ferromagnetic material with low retentivity and a suitable size range. Their color shall provide high contrast to the background on which applied. Particles shall be free from rust, fillers, or other material that could interfere with their use. Magnetic particle materials shall be used only once. Particle application and removal equipment (powder bulbs, aerosol sprays) shall be such that fine indications are not removed by excessive force.

G9. Equipment Performance Checks

The performance of the magnetic particle inspection system and procedures shall be checked at regular intervals. The yoke lifting force shall be checked each day, prior to performing any MT examination, and shall be documented.

G10. Yoke Placement

G10.1 Extent of Examination. Examination shall be conducted with sufficient overlap to ensure 100% coverage. However, if the geometry of the piece does not permit 100% evaluation of the piece, this shall be stated on the test report.

G10.2 Inspection of Discontinuities in the Longitudinal Direction. For inspection of discontinuities in the longitudinal direction, the yoke shall be placed astride and perpendicular to the weld. The yoke legs shall be positioned such that they are approximately 1/2 in to 1 in [12 mm to 25 mm] from the toe of the weld. Sufficient overlap shall be used to ensure 100% coverage when moving along the weld length.

G10.3 Inspection of Discontinuities in the Transverse Direction. For inspection for discontinuities in the transverse direction, the yoke shall be oriented so that the yoke legs are approximately parallel to the weld, approximately 1/2 in [12 mm] from the toe of the weld. If the yoke has to be placed on top of the weld to gain access, the technician shall ensure the best contact possible of the yoke legs to the weld.

G11. Particle Application and Removal

Dry particles shall be applied in such a manner that a light, uniform, dustlike coating of particles settles on the part while it is being magnetized. Particle indications shall be observed when being formed as the particles are being applied, and while the excess particles are being removed.

Sufficient air velocity for particle removal shall be directed at the area of inspection to remove the excess particles entrapped in areas such as weld undercut, while retaining the particles held primarily by magnetic flux leakage from the discontinuities.

G12. Interpretation and Evaluation of Indications

Relevant MT indications shall be defined as those that result from magnetic flux leakage fields formed by discontinuities that attract and hold magnetic particles.

Testing personnel shall verify indications by performing the following steps:

(1) Retest with the yoke field perpendicular to the discontinuity indication, if not already perpendicular.

(2) Retest, confirming that excess particles are removed. If the suspect indication is removed during the retest, the indication is interpreted as nonrelevant or as a false indication.

(3) If the indication has a light particle buildup and weak particle adhesion, and if doubt exists as to whether the indication is relevant or false, the area of the indication shall be lightly surface-ground and retested.

G13. Acceptance Criteria

All relevant indications, determined by MT to be cracks or incomplete fusion, shall be unacceptable, regardless of length.

Annex H (Normative)

Flaw Sizing by Ultrasonic Testing

This annex is part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, and includes mandatory elements for use with this standard.

H1. Flaw Sizing

When flaw-sizing techniques are implemented, ultrasonic testing and UT technician qualification shall be performed following written procedures as required by AWS D1.1/D1.1M Annex S. Acceptance criteria shall be in accordance with this clause.

H2. Acceptance Criteria

H2.1 Near-Surface Flaws. If a flaw is at or within 1/8 in [3 mm] of the surface, it shall be rejected and repaired or removed.

H2.2 Embedded Flaw Height. Embedded flaws, defined as those that do not come within 1/8 in [3 mm] of the surface, shall be rejected if their height exceeds 1/4 in [6 mm].

H2.3 Flaws at Steel Backing. When steel backing remains in place, the size of flaws that extend into the weld metal shall be determined. Flaws that extend more than 1/8 in [3 mm] into the thickness of the groove weld shall be rejected.

H2.4 Embedded Flaw Area. Embedded flaws shall be rejected if their area, calculated by multiplying the maximum discontinuity height by the maximum discontinuity length, exceeds the square of the effective weld throat. Embedded flaws, either individually or as a group within a length of weld 12 in [300 mm] or less, shall be rejected if they exceed a total area (the sum of the areas of individual discontinuities) equal to 10% of the effective weld throat multiplied by the weld length. The weld length used for this calculation shall not exceed 12 in [300 mm], with longer welds being evaluated in multiple parts. Discontinuity height and length shall be measured perpendicular to the direction of principal stress.

H2.5 Aligned Discontinuities. Aligned discontinuities of lengths L1 and L2, separated by less than (L1+L2)/2 shall be evaluated as continuous.

H2.6 Parallel Discontinuities. Parallel discontinuities of heights H1 and H2, separated by less than (H1+H2)/2 shall be evaluated as continuous.

H3. UT Technician Qualification for Flaw Sizing

H3.1 Personnel. Ultrasonic testing (UT) personnel shall be qualified in accordance with Annex F and shall demonstrate proficiency by satisfactory performance in an examination as prescribed in H3.2.

H3.2 Examination. The examination shall consist of practical tests that have been developed by the NDT Agency's UT Level III, or an organization approved by the Agency, and shall incorporate the specific requirements of the NDT Agency's procedures and the applicable weld quality acceptance standards contained in Clause H2. The examination shall utilize a UT procedure(s) that conforms to AWS D1.1/D1.1M Annex S for Flaw Sizing.

The examination shall also test the ability of UT personnel to correctly calibrate UT equipment and complete the relevant paperwork associated with the examination. Testing procedures and examination results shall be documented and available to the Engineer for review.

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Annex I (Informative)

Guidelines for the Preparation of Technical Inquiries for Structural Welding Committee

This annex is not part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, but is included for informational purposes only.

I1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

I2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

I2.1 Scope. Each inquiry shall address one single provision of the code, unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the code that contains the provision(s) the inquirer is addressing.

I2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a code's requirement, or to request the revision of a particular provision in the code.

I2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the code, the inquiry must provide technical justification for that revision.

I2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

I3. Interpretation of Code Provisions

Interpretations of code provisions are made by the Structural Welding Committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the code addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire Structural Welding Committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

I4. Publication of Interpretations

All official interpretations shall appear in the *Welding Journal* and will be posted on the AWS web site.

I5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning the *Structural Welding Code* should be limited to questions of a general nature or to matters directly related to the use of the code. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

I6. The Structural Welding Committee

The activities of the Structural Welding Committee regarding interpretations are limited strictly to the interpretation of code provisions or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) code requirements applied to fabrications outside the scope of the code or points not specifically covered by the code. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex J (Informative)

Informative References

This annex is not part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, but is included for informational purposes only.

American Welding Society (AWS) standards:[8]

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

[8] ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Commentary on Structural Welding Code— Seismic Supplement

2nd Edition

Prepared by the
AWS D1 Committee on Structural Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

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Foreword

This foreword is not part of AWS D1.8/D1.8M:2009, *Structural Welding Code—Seismic Supplement*, but is included for informational purposes only.

This commentary on AWS D1.8/D1.8M:2009 has been prepared to generate better understanding in the application of the code to welded construction of steel in seismic applications. Since the code is written in the form of a specification, it cannot present background material or discuss the Structural Welding Committee's intent; it is the function of this commentary to fill this need.

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Commentary on Structural Welding Code—Seismic Supplement

C-1. General Requirements

C-1.1 Applicability

This code is typically applicable to welded joints in Seismic Force Resisting Systems designed in accordance with the AISC Seismic Provisions. This code is not intended to be applicable to the design or construction of steel structures, or portions of steel structures, not designed in accordance with the AISC Seismic Provisions.

These provisions are intended to apply only to joints or members that are likely to experience yield level stresses or strains during a design seismic event, or whose failure would likely have a significant adverse impact on the performance of the Seismic Force Resisting System (SFRS). This will typically not include all welds on members of the SFRS. The Engineer is responsible to clearly identify on the construction documents those welds that are subject to the provisions of this standard (see 1.2.1).

The provisions of this code are intended to provide welded steel building structures with an ability to sustain the long term and short term loadings specified by the building codes with adequate serviceability and reliability. Seismic loads specified by the building codes are quite different from other loading conditions in that there is an inherent assumption that, when subjected to a seismic event, the building structure's Seismic Force Resisting Systems (SFRS) will undergo substantial inelastic response. Depending on the type of SFRS present in a building, its configuration and detailing, this inelastic response may result in inelastic straining of individual members of the SFRS or the connections of these members. The welded joints are detailed to resist yield strength stresses while the connections and/or members are intended to yield away from the weld.

Damage sustained by welded steel moment-frame buildings in the 1994 Northridge earthquake, and extensive research conducted by the FEMA/SAC program following that earthquake demonstrated that in order to obtain adequate performance of welded steel structures under conditions of severe inelastic straining, additional controls on design, detailing, materials, workmanship, testing, and inspection are necessary. This research resulted in substantive changes to the AISC Seismic Provisions, which control the design of steel SFRS as well as certain aspects of the materials and detailing of these systems. The provisions contained in this standard complement the AISC Seismic Provisions and are intended to ensure that welded joints that are designed to undergo significant repetitive inelastic strains as a result of earthquakes or that are used to connect members designed to resist such inelastic strains have adequate strength, notch toughness, and integrity to perform as intended. In general, the AISC Seismic Provisions specifies the requirements for design of members, connections and welded joints in the SFRS. AISC Seismic Provisions also specifies the requirements for a Quality Assurance Plan as well as the minimum levels of Quality Assurance that are appropriate for elements of the SFRS. This code, together with AWS D1.1/D1.1M, specifies the acceptable materials, procedures and workmanship for constructing welded joints in the SFRS as well as the procedures, and acceptance criteria for quality control and quality assurance inspection of welded joints in the SFRS.

Structures designed for earthquake resistance are expected to dissipate earthquake energy through extensive reversing, repetitive, inelastic straining. This is the explicit assumption of the AISC Seismic Provisions, as well as that of the building codes that reference these provisions.

This is a severe loading condition, which can result in development of fractures, unless proper proportioning of the members, detailing of the connections, control of the materials of construction, and quality control of the fabrication and erection is exercised.

In research performed following the 1994 Northridge earthquake, it was determined that analytical evaluation of the behavior of connections is not by itself sufficient to assure reliable behavior of structures subjected to these loading conditions. The 1997 and later editions of the AISC Seismic Provisions require that the performance capability of connections of certain structural systems designed for severe seismic service be demonstrated (qualified) through combined programs of analytical work and testing. The AISC Seismic Provisions permit this qualification to be performed on either a project-specific basis or on a more general prequalification basis. Regardless, reliable performance of these structures requires that the conditions of design, fabrication, and erection workmanship for which a connection was qualified be maintained in the production work. For this to occur, the Fabricator and Erector must be made aware of the portions of the structure that require special care. Subclause 1.2.1 requires the Engineer to provide the needed information to the Fabricator and Erector through the Contract Documents.

C-1.2 Responsibilities

C-1.2.1 Engineer's Responsibilities. This subclause provides a detailed list of information that the Engineer is to provide as part of the Contract Documents in order to completely delineate the design intent related to welded connections in the SFRS. The information to be provided should reflect the requirements of this code, the AISC Seismic Provisions, and (when applicable) the AISC Prequalified Connections requirements.

It is intended that this code be used in conjunction with AISC Seismic Provisions, and AISC Connection Prequalification. In future editions of AISC Seismic Provisions and the AISC Prequalified Connections document and this code, it is intended that overlapping requirements will be combined for consistency between the three documents. Where conflicts exist, the Engineer should coordinate and resolve the differences.

C-1.2.1 Items 2, 3, and 4. The AISC Seismic Provisions designate the members that are to be included in the SFRS, the definition of Protected Zones, and welds that are subject to special requirements beyond AWS D1.1/D1.1M (see Figures C-1.1, C-1.2, and C-1.3).

C-1.2.1 Items 5, 6, and 7. The presence of backing, weld tabs, and welds between these attachments and the members they are attached to may effect the flow of stresses around the connections and contribute to stress concentrations. Therefore, the AISC Seismic Provisions and AISC Prequalified Connections based on the AISC Seismic Provisions require the removal of these attachments in some locations. Some backing and tabs are in positions that make them difficult to remove without damaging the adjacent material and test data demonstrates that acceptable performance can be achieved without their removal. Removal of backing and tabs, and the addition of reinforcing fillet welds, are details that should be evaluated on a joint specific basis. The AISC Seismic Provisions and connection qualifications and prequalifications based on those provisions specify these requirements. In general, it is not necessary to remove backing and weld tabs unless so specified. It is the Engineer's responsibility to incorporate in the Contract Documents all such requirements. Table C-1.1 shows the frequently used practice for disposition of weld tabs and backing for some common connections. Specific details must be verified with governing documents.

C-1.2.1 Item 5. In addition to this code, both AISC Seismic Provisions and AISC Prequalified Connections provide requirements regarding steel backing removal. Backing removal may be impractical and unnecessary in locations such as column splices. Backing removal is impossible at the inside corners of small box sections, and at column splices of box sections. Some AISC connection qualifications have been performed with backing remaining in place, thus removal is not justified for those applications. It is costly, and unnecessary, to require backing to be removed from all connections (see C-6.7 and combined Commentary C-1.2.1 Items 5, 6, and 7).

C-1.2.1 Item 6. In addition to this code, both AISC Seismic Provisions and AISC Prequalified Connections provide requirements regarding where steel backing may remain in place, provided a fillet weld is applied to reduce the stress concentration associated with the left-in-place backing. Analysis and testing has demonstrated that the naturally occurring unfused edge of steel backing that contacts the column face in a beam to column connection constitutes a severe stress raiser. By placing a fillet weld between the steel backing and the column face, this concentration can be significantly reduced. Contract Documents are required to show where this treatment of the backing is required (see 6.9, C-6.9, and combined Commentary C-1.2.1 Items 5, 6, and 7).

C-1.2.1 Item 7. In addition to this code, both AISC Seismic Provisions and AISC Prequalified Connections provide requirements regarding weld tab removal. Such removal may be impractical, or even harmful, in some situations. In general, weld tabs should not be used in the k-area, but if used, are best left in place rather than risking the damage that might occur during tab removal (see 6.11.3, 6.11.4, C-6.11.4, and combined Commentary C-1.2.1 Items 5, 6, and 7.

C-1.2.1 Item 8. In addition to this code, both AISC Seismic Provisions and AISC Prequalified Connections provide requirements regarding the use of reinforcing fillet welds. Such locations are typically in tee and corner joints, where the seismically induced loads are perpendicular to the weld axis, and where the reinforcing fillet weld, applied to a CJP groove weld, reduces the stress concentration of a nearly 90° intersection between the weld face or root, and the adjacent steel member. A typical location is at the groove weld to column face juncture of beam to column connections. Such reinforcement is not required for most groove welds in tee or corner joints, and is not feasible for groove welds in butt joints, such as column splices (also see 6.7 and C-6.8).

C-1.2.1 Item 9. In addition to this code, both AISC Seismic Provisions and AISC Prequalified Connections provide requirements regarding the use of access holes. Analysis and research have shown that the shape of the weld access hole can have a significant effect on the behavior of moment connections (see 6.10.1, 6.10.2, 6.10.3, and related commentary). The use of different weld access holes, other than that prescribed by AWS D1.1/D1.1M, has not been found necessary for locations such as column splices. Care should be exercised to avoid specifying special weld access hole geometries when not justified. In some situations, no weld access holes are desirable, such as in end plate connections.

C-1.2.1 Item 10. The majority of welded connection applications in buildings are in temperature controlled settings. Where connections are subjected to temperatures of less than 50°F [10°C] during service, additional requirements for the weld consumables may be necessary to ensure adequate resistance to fracture at the lower service temperatures.

C-1.2.1 Item 11. The 2005 AISC Seismic Provisions provide requirements beyond AWS D1.1/D1.1M for welded butt joints in column splices to provide for smoother flow of stresses through these critical joints.

C-1.2.1 Item 12. In common frame configurations, specific assembly order, welding sequence, welding technique, and other special precautions beyond those provided in this document should not be necessary. It is anticipated that such additional requirements will only be required for special cases, such as those of unusually high restraint.

C-1.2.1 Item 13. A Quality Assurance Plan (QAP) is required by many Building Codes, the AISC Seismic Provisions, and AISC Prequalified Connections. The QAP is required to be prepared by the Engineer, and is required to be included as part of the Contract Documents. It is essential that the QAP be provided to the Contractor as part of the bid documents as any special Quality Assurance or Quality Control requirements could have substantial impact on the cost of the work. Annex Q of the AISC Seismic Provisions specify the minimum acceptable requirements for a QAP that applies to the construction of welded joints in the SFRS. The QAP as contained in Annex Q is recommended for adoption without unnecessary revision because consistent application of the same requirements is expected to improve reliability.

C-1.2.2.3 Product Data Sheets. The welding variables, storage, exposure, and baking (if applicable) recommendations for FCAW and composite GMAW electrodes are product specific. It is important to obtain the manufacturer's recommendation regarding the relation between voltage and current for FCAW and composite GMAW electrodes. The AWS D1.1/D1.1M tolerances may be applied to these recommended values, provided other requirements, such as heat input limitations, are met.

Variables such as amperage (or wire feed speed, if used), voltage, and electrode extension (also called "stickout") are typically supplied by filler metal manufacturers as these variables must be balanced in order to obtain acceptable welding conditions. Travel speeds are directly dependent upon the weld type being made, and filler metal manufacturers do not typically supply this data.

For SMAW, only current is required to be controlled. The welding current recommendations for SMAW electrodes are product specific. The AWS D1.1/D1.1M requirements for exposure, storage, and baking are considered adequate for SMAW electrodes.

Solid wire electrodes for ESW, EGW, SAW, and GMAW are generic products that do not have manufacturer unique voltage and current characteristics. Some information on welding variables may be found in the AWS *Welding Handbook*. Various other "how to" booklets, and procedure guides provide information on welding current and melting rates, voltage adjustments, and some typical applications.

Solid wire electrodes do not have exposure limits or specific storage requirements other than to be kept clean and dry. Thus, some major manufacturers of solid wire electrodes do not provide recommendations for welding variables, exposure, and storage on the product data sheets.

C-1.2.2.4 Hydrogen Content. See 6.3.2 and C-6.3.2. Documentation is not required for all filler metals. Exemptions are contained in 6.3.2. The documentation will typically be a Certificate of Conformance. This provision does not require lot-specific hydrogen testing of the filler metal to be used.

C-1.2.2.5 Extended Exposure Capability of FCAW Filler Metals. Subclause 6.4.3 provides two bases for extended exposure of filler metals, both of which require testing of the filler metal in accordance with Annex E. This documentation will normally consist of a test report that records the testing conditions, and the measured diffusible hydrogen level of welds made with the exposed electrode. This provision does not require lot-specific testing of the filler metal to be used.

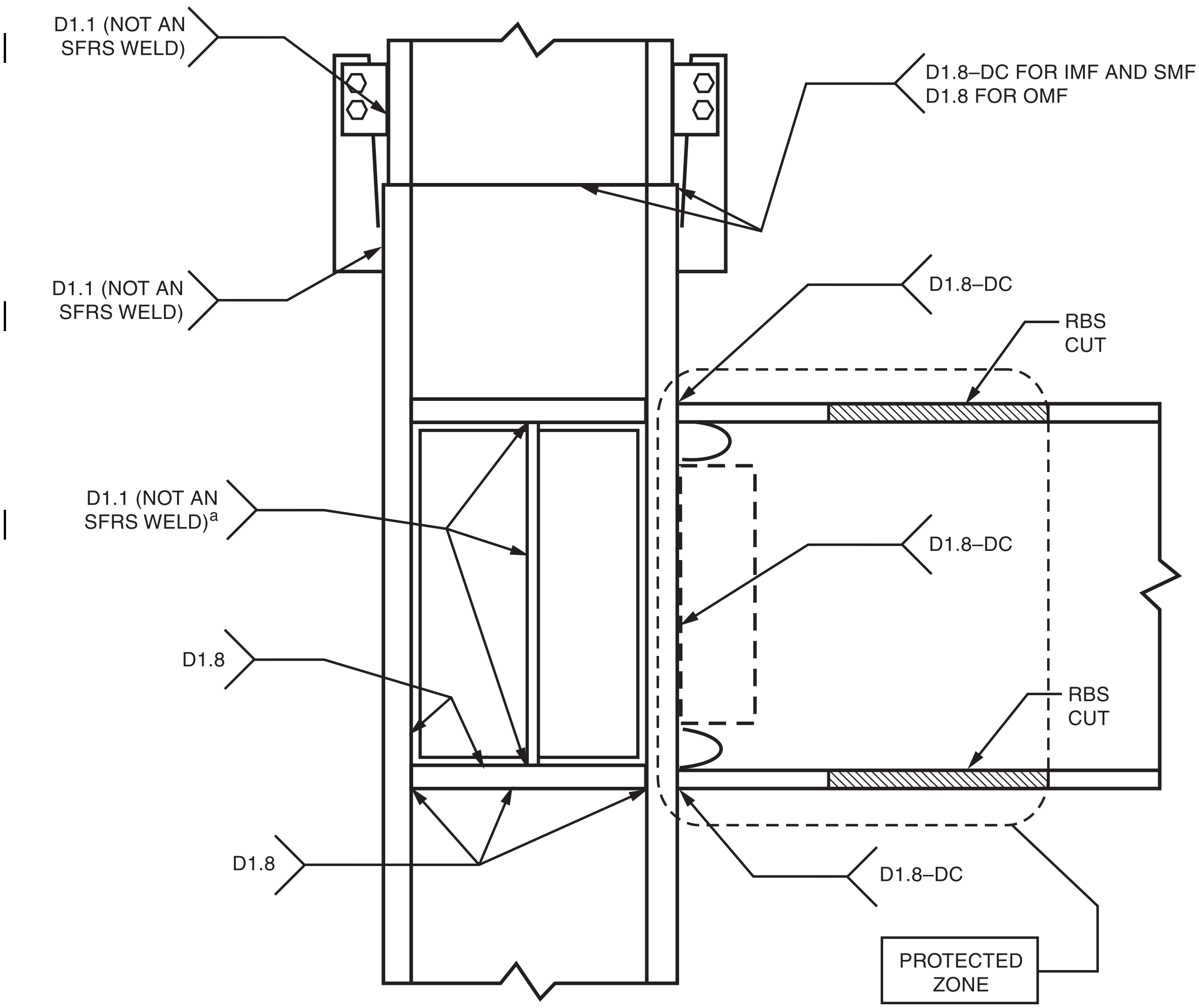
C-1.2.2.7 Supplemental Welder Qualification Testing Documentation. See Annex D and corresponding commentary.

C-1.3 Limitations

These provisions have been developed based on tests and the historic usage of beams with minimum specified yield strengths of 55 ksi [380 MPa] or less. Plastic hinging in steel of this strength range has been extensively tested. This code additionally covers applications where steels with minimum specified yield strengths of up to 70 ksi [485 MPa] are permitted, although members made of such steels are not expected to contain the plastic hinge region (except perhaps for panel zone yielding in columns). Such applications of steel with minimum specified yield strengths of 70 ksi [485 MPa] would include columns. The provisions within this code are not expected to be sufficient for design, fabrication, and inspection of structures made of steels that exceed these limits.

Table C-1.1
Removal of Tabs and Backing

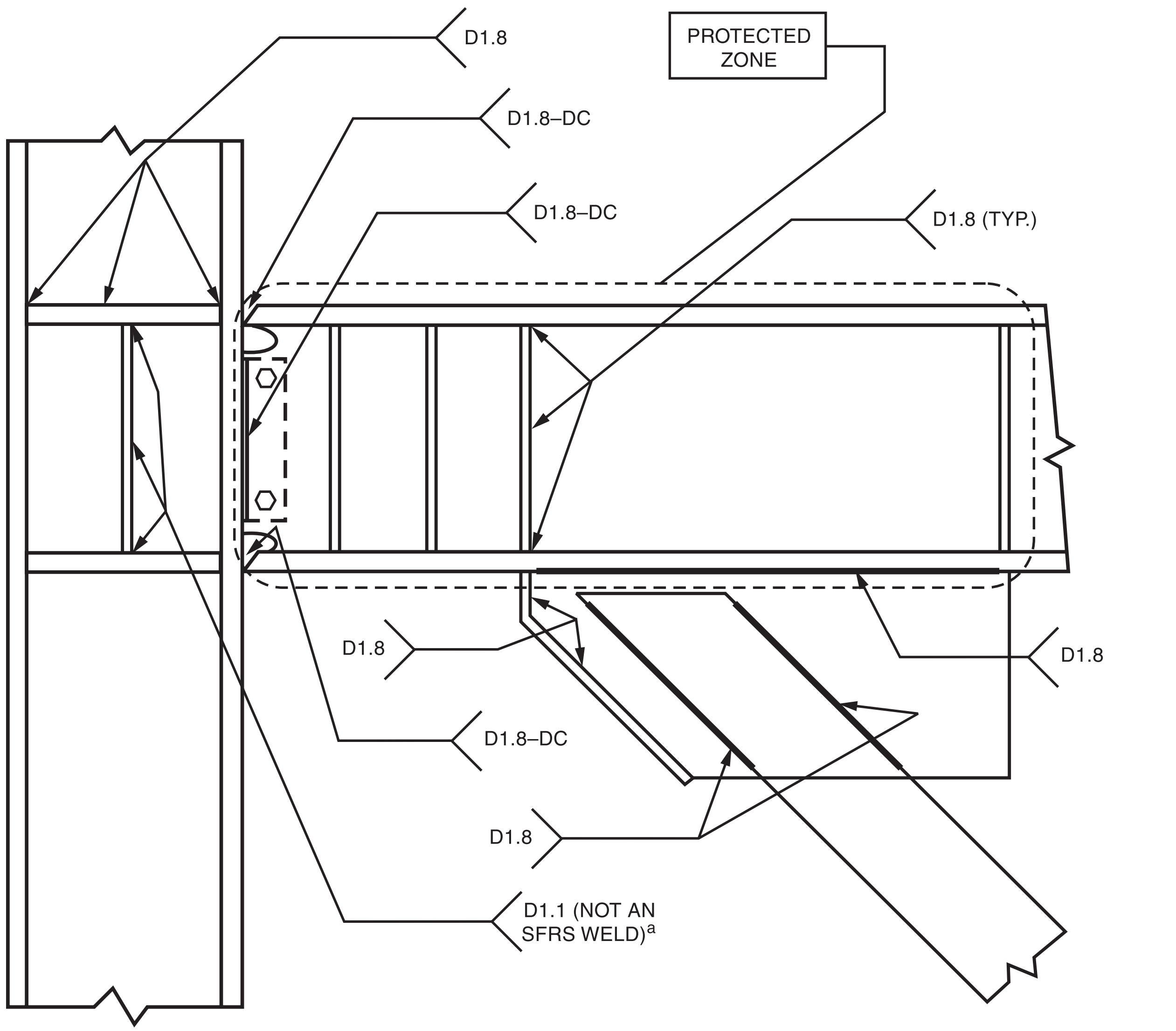
	Tabs	Backing
Prequalified Moment Connection (see AISC Connection Prequalification)		
Qualified Moment Connections (see AISC Qualification Tests)		
Moment Frames		
Top Flange—Column Flange	Remove	Remain with fillet weld to column (not to beam)
Bottom Flange—Column Flange	Remove	Remove
Continuity Plates	—	Remain with fillet weld to column
	At column fillet (e.g., near the k-area) Not recommended (see 6.11.4)	—
	Near column flange tip Remove	—
Concentrically Braced Frames (CBF)		
All Brace Connection Joints	Remain	Remain
Eccentrically Braced Frames (EBF)		
Links to Columns	Remove	Same as Moment Frame
Braces to Links	Remove	Remove
All Other Brace Connection Joints	Remain	Remain
Column Splices (for Moment Frames, CBF, EBF)		
Column Splices	Remove	Remain



[a] As shown, the member connecting to the weak axis is not an SFRS member.

Notes:
1. D1.8–DC indicates welds commonly designated Demand Critical joints.
2. D1.8 indicates joints subject to the requirements of D1.8, but not commonly designated Demand Critical welds.
3. D1.1 indicates joints subject to the requirements of D1.1 only.

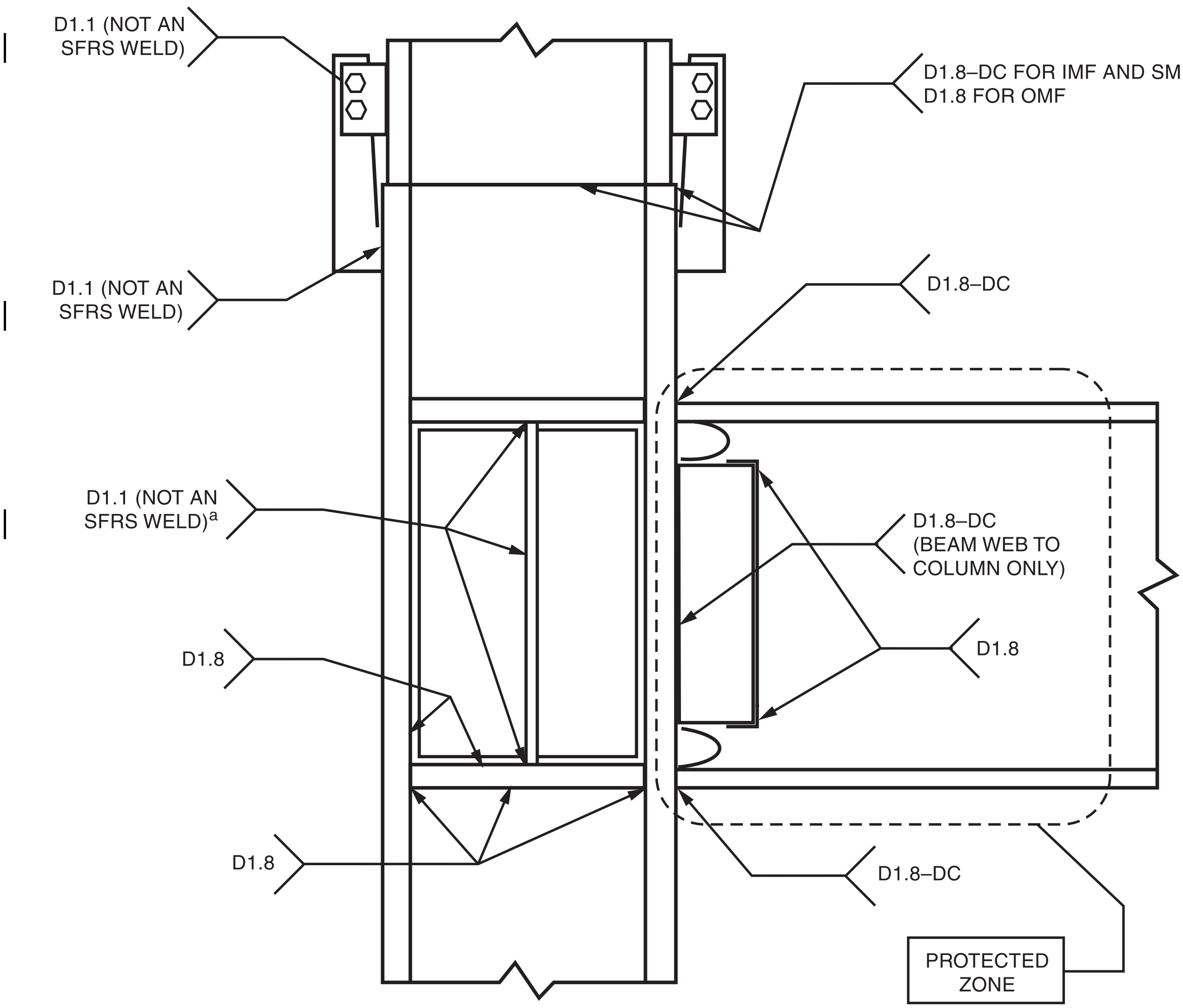
Figure C-1.1—Example RBS/Column Strong Axis Connection (see C-1.2.1 Items 2, 3, and 4)



[a] As shown, the member connecting to the weak axis is not an SFRS member.

Notes:
1. D1.8–DC indicates welds commonly designated Demand Critical joints.
2. D1.8 indicates joints subject to the requirements of D1.8, but not commonly designated Demand Critical welds.
3. D1.1 indicates joints subject to the requirements of D1.1 only.

Figure C-1.2—Example Eccentric Brace/Link/Column Connection (see C-1.2.1 Items 2, 3, and 4)



[a] As shown, the member connecting to the weak axis is not an SFRS member.

Notes:

1. D1.8–DC indicates welds commonly designated Demand Critical joints.
2. D1.8 indicates joints subject to the requirements of D1.8, but not commonly designated Demand Critical welds.
3. D1.1 indicates joints subject to the requirements of D1.1 only.

Figure C-1.3—Example WUF-W/Column Strong Axis Connection (see C-1.2.1 Items 2, 3, and 4)

C-3. Terms and Definitions

C-3.1 Seismic Force Resisting System

The AISC Seismic Provisions provides definitions and examples of members of the Seismic Force Resisting System.

C-3.2 Demand Critical Welds

The term "Demand Critical welds" is used to identify welds subject to extra requirements of this code. Demand Critical welds are further defined in AISC Seismic Provisions. The requirements are intended to reduce the likelihood of fracture. The requirements applicable to Demand Critical welds are identified in the text of this code. The Engineer is required by 1.2.1(4) to identify Demand Critical welds in the Contract Documents.

Demand Critical welds are designed based on expected yield level or higher stress demand, or are those joints the failure of which would result in significant degradation in the strength and stiffness of the SFRS. Demand Critical joints typically include:

(1) Those identified to be Demand Critical as a result of connection prequalification analysis in accordance with AISC Seismic Provisions Appendix P,

(2) Those identified to be Demand Critical in connection qualification testing in accordance with AISC Seismic Provisions Appendix S,

(3) Those identified to be Demand Critical in AISC 358.

Figures C-1.1 and C-1.2 illustrate typical Demand Critical welds in moment connections and Eccentrically Braced Frames (EBFs).

C-3.3 Protected Zone

Seismic Force Resisting Systems designed in accordance with the AISC Seismic Provisions are intended to dissipate earthquake energy through inelastic deformation in specific members and/or their connections. The locations within the structures in which such behavior is anticipated to occur are commonly termed plastic hinges. The Protected Zone is intended to encompass those portions of the structure in which plastic hinges are anticipated to form. Special care in the selection of materials, members, details, fabrication procedures, and quality control are required in these Protected Zones to avoid failure during earthquake response (see Figures C-1.1 and C-1.2 for typical examples).

C-3.4 Quality Assurance Plan

The requirements for a QAP are specified by Appendix Q of the AISC Seismic Provisions. The activities stipulated in this provision may have a significant impact in the organization of the work and cost of the project. The Quality Assurance Plan should alert the Contractor when, in the time line of construction, Quality Assurance activities are intended to occur.

C-3.5 LAST

LAST can conservatively be taken as the lowest outdoor temperature within the indicated recurrence interval. Conditions of insulation and exposure may permit a calculated increase in LAST relative to outdoor temperatures.

C-3.6 k-Area

In rotary straightened sections, a localized region known as the k-area may exhibit significantly altered mechanical properties due to cold working during mill processing. Property changes are known to include an increase in hardness, yield strength, ultimate tensile strength, yield tensile ratio, and a decrease in notch toughness (see Figures C-4.1 and C-4.2).

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C-4. Welded Connection Details

C-4.1 Corner Clips of Continuity Plates and Stiffeners

Some straightening processes used by mills to ensure that structural shapes are within the rolling tolerances of ASTM A 6 result in extensive cold working of the webs of rolled shapes in and near the k-area. This region is defined in 3.6. This cold working can result in the altering of properties within the affected area. Property changes are known to include an increase in hardness, yield strength, ultimate tensile strength, yield tensile ratio, and a decrease in CVN toughness. In some instances CVN toughness has been recorded to be less than 2 ft·lbs at 70°F [3 J at 20°C]. Fractures have been found to extend from cuts, punches, and welds in and on these shapes in the areas of reduced notch toughness. This provision is intended to minimize the potential for such cracking during fabrication.

When the code-mandated minimum clip dimensions are imposed, the available material on which a weld may be placed must be considered in the design and detailing of the welds to the clipped member. When fillet welds are used, the length of the fillet weld may be held back one to two weld sizes. For groove welds, weld tabs should not be used in the k-area (see 6.11.4). Corner clips are special cases for which minimum radii have been established by this provision and the general AWS D1.1/D1.1M requirement for reentrant corners does not apply (see Figures C-4.1 and C-4.2).

AISC and SAC investigations have shown that the locally altered properties do not negatively influence the in-service behavior of uncracked wide flange shapes. However, the potential for post-fabrication k-area cracking has been demonstrated in highly restrained joints at stress raisers at the termination of welds such as those associated with column continuity plates, web doublers, and thermally cut coped beams. However, rare instances of k-area cracking have occurred from bolt holes and square cut beam ends, both with relatively smooth finishes.

To minimize the potential for k-area cracking, it is recommended, where practical, that welding into the k-area should not be performed. Where k-area welding cannot be practically avoided, the reduction of residual stresses by increased preheat, proper weld sequencing, and minimization of weld volume is strongly suggested. The condition of beam copes and weld access holes flame cut surfaces can be improved by grinding to a smooth surface.

C-4.2 Tapered transitions are only required when specified in accordance with 1.2.1(11).

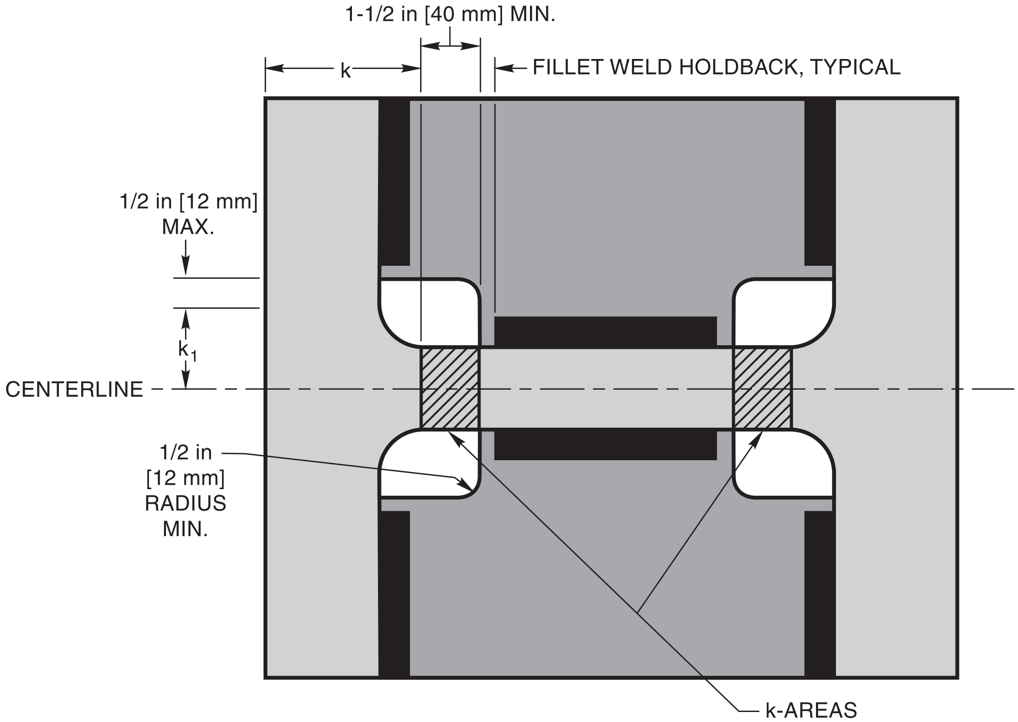

Figure C-4.1—Curved Corner Clip (see C-4.1)

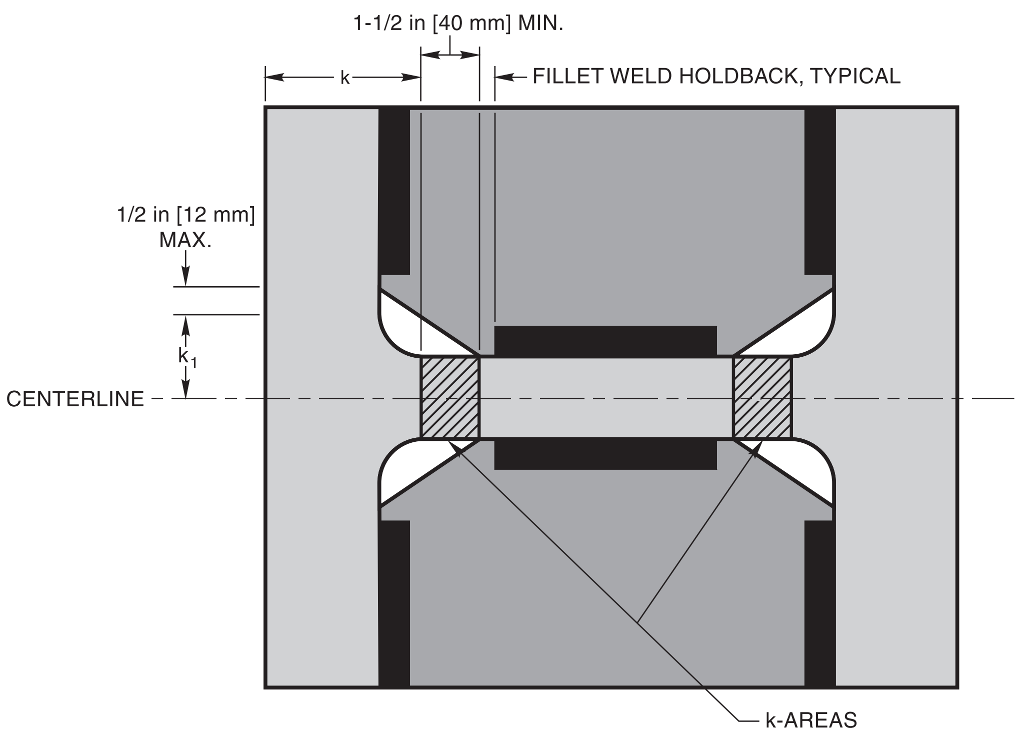

Figure C-4.2—Straight Corner Clip (see C-4.1)

C-5. Welder Qualifications

C-5.1 Supplemental Welder Qualification Testing

C-5.1.1 Required Tests. Some connections that fractured during the Northridge earthquake revealed problems associated with the welding of bottom beam to column flange connections. Incomplete fusion and slag inclusions were found concentrated in the center of the length of the weld, under the beam web. It is at this location that the welder must work through the weld access hole. The Supplemental Welder Qualification test described in Annex D was developed to measure the ability of a welder to make quality welds under these restricted conditions. The test was adapted from a similar test described in FEMA 353. The Supplemental Welder Qualification test does not replace the need for welders to be qualified in accordance with AWS D1.1/D1.1M requirements. This Supplemental Welder Qualification testing is only required for welders who will make welds meeting all three of the conditions prescribed in this provision.

C-5.1.2 Testing Parameters. The Supplemental Welder Qualification for Restricted Access Welding testing is required to be performed using the same process (e.g., FCAW, GMAW, SAW, SMAW, etc.) that will be used in production. The testing must also be performed with highest deposition rate that will be used with that process for the beam to column welds made in production. The WPS used for the qualification test is not required to be the same WPS as will be used in production. The electrode type, diameter, amperage, voltage, electrode manufacturer, and other variables used in production may be different than those used for the Supplemental Welder Qualification testing, providing the welding process is not changed, and the deposition rate used for the qualification test is not exceeded in production.

C-5.1.3 Backing. The type of backing is an essential variable for the Supplemental Welder Qualification for Restricted Access Welding test. Welders must be qualified to weld on each type of backing that will be used on a project. Separate welder qualification is required for different types of backing (i.e., copper or ceramic), and separate qualification is required to weld open root joints, if those types of backing or joints are used in production. Separately, WPS qualification is required by AWS D1.1/D1.1M for nonsteel backing. A common test specimen can be used to qualify welders and the WPS, providing all the required tests for both welder qualification, and WPS qualification, can be taken from the test specimen.

C-5.2 Welder Qualification Period

The 36-month period was arbitrarily selected as a reasonable period for applicability. For welders that are welding on a project and the arbitrary 36 months expires while the individual is actively making welds that meet the project weld quality standards, there is no need to requalify the welder on the Supplemental Welder Qualification for Restricted Access test as long as the welder continues to work on the same project.

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C-6. Fabrication

C-6.1 Welding Procedure Specifications (WPSs)

WPSs for Demand Critical welds are required to be based on the heat inputs used for the testing described in Annex A. Since the heat input testing could be different for each manufacturer and filler metal type, the Contractor is required to record the filler metal manufacturer and trade name of the product used in the WPS. The parameters chosen for the WPS must be within the heat input range used for the WPS Heat Input Envelope Test. If the Contractor chooses to note parameter "ranges" on the WPS, it will be necessary to verify that the full range on the WPS is within the heat inputs used in the WPS Heat Envelope Test. It is not necessary for the Contractor to use the exact parameters listed in the WPS Heat Input Envelope Test (volts, amps, travel speed), but the parameters chosen must result in a calculated heat input between the high and low heat inputs tested. The AWS D1.1/D1.1M heat input calculation will be used to calculate heat input and establish the WPS parameters, e.g., Heat Input (kJ/in.) = (60 × volts × amps)/(1000 × travel speed) (in inches per minute) [Heat Input (kJ/mm) = 60 × volts × amps/1000 × travel speed (in mm per minute)].

WPSs may show a range of acceptable values for certain welding variables. Some of these variables will affect deposition rates. Such variables include amperage, electrode diameter, electrical extension (electrical stick out), and polarity. For welds where the welder qualification includes a qualified maximum deposition rate, the WPS used in production for those joints requiring such welder qualification are required to show limits that will ensure that the welder will not exceed the maximum deposition rate for which he/she is qualified.

C-6.2 Welding Processes

C-6.2.1 Approved Processes for Demand Critical Welds. Prequalification and qualification of connection details is governed by AISC Seismic Provisions, and should not be confused with prequalification and qualification of WPSs, which is governed by AWS D1.1/ D1.1M.

SMAW and FCAW have been successfully used for connection qualification testing in the U.S., and in Japan, GMAW has been used. SAW, although not specifically known to have been tested in seismic moment connections, has been included in these approved processes because appropriate mechanical properties can be achieved with the process, and heat input levels may be similar to those employed in other tests. These processes are also those with which prequalified WPSs may be used. There is not a sufficient database of test results that documents the acceptability of processes such as ESW and EGW, and thus, these processes are not permitted to be used without specific supporting connection qualification tests, or as approved by the Engineer.

Specific WPS parameters are not required to be qualified by connection qualification tests. Unless approved by the Engineer, processes other than those listed in 6.2.1 (but not the specific WPS parameters) are required to be tested in the connection qualification tests. The essential variables of AWS D1.1/D1.1M still apply, and while the WPS may require a retesting, the connection test need not be replicated for changes in WPS essential variables.

The ability of moment-resisting connections to successfully dissipate earthquake energy is dependent on a large number of factors including connection geometry, member size, strength, notch toughness, and chemical composition of the base metals, welds, and heat-affected zones (HAZs), as well as other factors. A large number of laboratory tests and analytical investigations were conducted to confirm that connections having certain geometry, material and construction characteristics could perform acceptably. Joints welded with processes other than the prequalified processes were not included in the scope of investigations that serve as the basis for these documents. However, the AISC Seismic Provisions recommend procedures for verifying that connections employing alternative geometric, design, or construction features are capable of acceptable performance. It is recommended that the Engineer consider using the same connection qualification methods contained in the AISC Seismic Provisions as the basis for approval to qualify the use of welded joints employing processes other than the four prequalified processes listed in 6.2.1. Alternatively, tests that consider the effect of the welding process on HAZ properties, the propensity of the process to produce various weld discontinuities, and the inspectability of joints made with these processes, could be used as the basis for approval.

C-6.2.2.1 Gas-Shielded Processes. Weld metal ductility and CVN toughness has been shown to degrade with increasing air velocity and loss of shielding when gas-shielded processes are used. Before porosity is seen, notch toughness has been shown to decrease. With wind speeds of 8 mph to 10 mph [3.6 m/s to 4.5 m/s], welds may have significant internal porosity without visual indication of surface-breaking porosity (References: FEMA 355B, *State of the Art Report on Welding and Inspection*, Chapter 6, Federal Emergency Management Agency, 2000, and SAC/BD-00/12, *Evaluation of the Effect of Welding Procedure on the Mechanical Properties of FCAW-S and SMAW Weld Metal Used in the Construction of Seismic Moment Frames*, M. Q. Johnson, 2000.)

Precise monitoring of wind speed is not intended by this provision. Three mph winds [5 kph] will cause modest drifting of smoke or welding fume. Higher speed can be felt on the face and as well as cause modest rippling of water surfaces. Wind velocity is to be estimated in the immediate weld area rather than in the general atmospheric condition.

AWS D1.1/D1.1M has a maximum wind speed limit of 5 mph [8 kph]. This has been deemed acceptable since AWS D1.1/D1.1M does not have mandatory CVN toughness requirements. The more conservative value of this code has been imposed due to the concern for CVN toughness of welds that are part of the SFRS.

C-6.2.2.2 Non Gas-Shielded Processes. The self-shielded processes listed are considerably more tolerant of air velocity. In SMAW, the electrode flux provides a gas to shield the arc and a slag blanket to protect the molten metal droplets and the weld pool. In SAW, the metal droplets and weld pool are covered by the granular flux.

In FCAW-S, shielding is provided by vaporized flux ingredients that displace the air, a slag composition that covers the molten metal droplets and the weld pool, and a weld metal composition that protects the weld metal from the potentially harmful effects of nitrogen. Compared to FCAW-G, which showed significant decrease in CVN toughness with increasing wind speed, no effect on CVN toughness was noted for FCAW-S for wind speeds of 18 mph [8 m/s]. (Reference: FEMA 355B, State of the Art Report on Welding and Inspection, Chapter 6, Federal Emergency Management Agency, 2000) (SAC/BD-00/12, Evaluation of the Effect of Welding Procedure on the Mechanical Properties of FCAW-S and SMAW Weld Metal Used in the Construction of Seismic Moment Frames, M. Q. Johnson, 2000.)

C-6.3 Filler and Weld Metal

C-6.3.1 AWS A5 Specification Properties. The yield, tensile, and elongation properties contained in Table 6.1 are minimum values—higher values are acceptable. No maximum values have been placed upon the yield or tensile strength of the weld metal. Welds are not designed to participate in inelastic strain mechanisms, so higher weld metal strengths do not affect deformation capabilities in that inelastic strains are not expected to be concentrated in welds.

The CVN toughness properties listed in Table 6.1 are minimum values. Higher absorbed energy values (ft•lbf) [J] are acceptable. Testing at lower temperatures (such as –40°F [–40°C]) is more demanding, and therefore, filler metals tested at lower temperatures are acceptable, providing the minimum absorbed energy level (e.g., 20 ft•lbf [27 J]) is achieved.

C-Table 6.1 Filler Metal Classification Properties. A variety of weld metal CVN requirements have been developed in the post-Northridge era. FEMA 267 (August 1995) stated that "for critical joints" (later defined as beam to column CJP groove welds), a "minimum CVN value of 20 ft•lbs at a temperature of 0°F should be required, unless more stringent requirements are indicated by the service conditions and/or the Contract Documents." This testing was to be done in accordance with the AWS filler metal specifications (see FEMA 267, page 8-11).

AISC Seismic Provisions (April 1997) incorporated the general concepts contained in FEMA 267, and incorporated them into provision 7.3b. This provision required that CJP groove welds in the SFRS be made with a filler metal with a minimum CVN toughness of 20 ft•lbs, but the testing temperature was changed from 0°F to –20°F.

In FEMA 353 (July 2000), the FEMA 267 recommendations for CVN notch toughness of 20 ft•lbs @ 0°F was retained, but the coverage was expanded to include "all welds on members comprising the Seismic Force Resisting System". Additionally, all welds were recommended to meet 40 ft•lbs at 70°F, when tested in accordance with procedures as prescribed in Appendix A of FEMA 353.

These procedures are similar to those required by Annex A of this code (see FEMA 353, Part I: 2-3).

AISC Seismic Provisions (May 2002) incorporated the general concepts contained in FEMA 353, identifying two types of welds: type 7.3a welds (all welds that are part of the SFRS) and type 7.3b welds (certain CJP groove welds in specific situations). For the 7.3a welds, the filler metals were required to be classified with CVN notch toughness of 20 ft•lbs at –20°F. For the 7.3b welds, an additional CVN requirement of 40 ft•lbs at 70°F was required, as determined by Appendix X of the AISC Seismic Provisions. Appendix X was similar to FEMA 353 Appendix A, and Annex A of this code.

The AISC Seismic Provisions (March 2005) revised the requirement for welds that are part of the SFRS (7.3a), changing the filler metal classification CVN toughness to 20 ft•lbf at 0°F or a lower temperature, rather than 20 ft•lbf at –20°F. The requirements for what was termed "Demand Critical" welds (7.3b) remained unchanged, e.g., filler metals must be classified with a CVN toughness of 20 ft•lbf at –20°F or lower temperature, and an additional requirement of 40 ft•lbf at 70°F or lower temperature as determined by Appendix X of the Seismic Provisions.

This code has incorporated the concepts of two weld types (part of the SFRS, and Demand Critical welds), and two CVN requirements: 20 ft•lbs in the AWS classification test, and 40 ft•lbs [54 J] at 70°F [20ºC] in the Annex A test. Toughness at the service temperature is the relevant property, therefore, this code requires the classification test temperature be 0°F for all welds as was recommended in FEMA 267 and FEMA 353, not the –20°F temperature as required for all welds part of the SFRS by AISC Seismic Provisions (both 1997 and 2002) or for Demand Critical welds by AISC Seismic Provisions (2005). As specification requirements continue to develop, it is important for Contract Documents to address any inconsistencies that may exist between specifications (see C-1.2.1).

C-6.3.2 Diffusible Hydrogen Level. All welding electrodes for processes approved by this code (see 6.2.1) are expected to meet the diffusible hydrogen requirements for H16. This requirement also applies to each SAW electrode/flux combination to be used on the project. Carbon steel FCAW electrodes are required to meet the further testing restrictions described in A5.20/A5.20M Clause 16. If low alloy FCAW electrodes are tested to the diffusible hydrogen requirements in A5.20/A5.20M Clause 16 and meet the requirements of H16 or less they are acceptable for use in Demand Critical welds. It is also acceptable for low alloy FCAW electrodes to be tested for diffusible hydrogen in accordance with AWS A5.29/A5.29M and AWS A4.3. Costly testing and schedule impact can be easily avoided by requesting this information from the electrode and flux manufacturers.

The applicable filler metal specifications for FCAW, GMAW, SAW, and most SMAW electrodes do not require testing to determine diffusible hydrogen content. However, such testing is required to be performed if the optional diffusible hydrogen designators are used. This code requires that the filler metals used not exceed a diffusible hydrogen content of 16 ml/100 g. Documentation of conformance to the testing prescribed is required (see 1.2.2.4). SMAW electrodes may be accepted based upon moisture content.

C-6.3.4 Intermix of FCAW-S Filler Metal. Research has found the intermixing of the self-shielded flux cored arc welding process (FCAW-S) and electrodes with other welding processes and electrodes may exhibit some degradation of notch toughness values in the intermixed deposit. Testing of intermixed weld metal is only required when the FCAW-S process is used in combination with any other welding process. This testing is done to ensure the minimum notch toughness requirements are met. No other process combinations are required to be tested by this code. This provision does not require intermixed combinations of various FCAW-S electrodes to be tested.

A variety of intermix tests were performed before the issuance of this code. These would include both tests performed in accordance with FEMA 353, as well as research performed in conjunction with various SAC investigations. Even though some of the details of these other tests might be slightly different than those of Annex B, alternative test results may be accepted by the Engineer. The Engineer should evaluate the relative similarity of the alternative tests to those required by this code, and FEMA. The Contractor should provide sufficient background documentation to the Engineer for this evaluation.

C-6.3.5 WPS Heat Input Envelope Testing Properties. The purpose of WPS Heat Input Envelope Testing prescribed in Annex A is to demonstrate that the required strength, ductility, and CVN toughness will be achieved and to avoid needless repetitions of welding procedure qualification tests. Weld cooling rates as determined by heat input, preheat, interpass temperature, and material thickness are known to affect mechanical properties of weld metal and heat-affected zones. While all welds and base metals are affected to some extent, the influence of cooling rates becomes more pronounced in high yield strength steel, particularly those steels that are quenched and tempered, and "matching" weld metals which require martensitic or bainitic microstructures for the required properties. The structural steels used in building construction and the E70 and E80 filler metals are less sensitive to weld cooling rates, particularly in terms of yield and tensile strength. Notch toughness properties, as measured by CVN specimens, are more significantly affected by cooling rates.

This code does not require that WPSs be qualified by test. However, to ensure that the required mechanical properties are achieved in production, this code requires that the filler metal to be used in making Demand Critical welds be evaluated at a high and low heat input level. The Contractor may then use any combination of WPS values that result in a heat input level between the high and low value. Compliance with AWS D1.1/D1.1M prequalified WPS provisions is still required. The welding progression, whether a weave bead or stringer bead, is not limited by this code, provided that the heat input range is maintained. The AWS D1.1/D1.1M limitations on layer thickness and width, coupled with the heat input limitations of this code, are considered to be adequate controls on weld metal mechanical properties.

The 40 ft•lbf [54 J] CVN energy absorption level was established by research performed in conjunction with the SAC project. The 70°F [20°C] test temperature was established by the same research. This value is typically appropriate for enclosed buildings. When specified by the Engineer as required by 1.2.1(10), alternate test temperatures may be required.

CVN testing of weld metal in accordance with Annex A, but performed at a temperature lower than 70°F [20°C], automatically meets the CVN requirements of Table 6.2 since this is a more demanding testing condition. The absorbed energy level of 40 ft·lbf [54 J] is a minimum requirement; higher values are acceptable.

Regardless of the welding process or the filler metals involved, the expectation is that Demand Critical welds have the properties listed in the Table 6.2. SMAW performed with either E7018 or E8018 electrodes, or GMAW performed with solid electrodes, routinely deposit welds with these mechanical properties and therefore, it is not required to perform the tests required by Annex A for these processes/filler metals.

Subclause 6.1.3 of this code requires that WPSs be operated within the range of heat inputs, a heat input envelope, which have been tested. Carbon steel FCAW electrodes classified with the supplemental designator "-D" have been heat input envelope tested by the manufacturer as described in Clause 17 of AWS A5.20/A5.20M:2005. The prescribed testing required to classify a filler metal with the supplemental designator "-D" is similar, but not identical to, the testing defined in Annex A, and are exempt from Annex A testing for use in Demand Critical welds as defined by this code. As of the time of publication of this document, AWS A5.29/A5.29M does not include heat envelope testing. Low Alloy FCAW electrodes classified to AWS A5.29/A5.29M that have been optionally tested by the filler metal manufacturer as described in AWS A5.20/A5.20M:2005 Clause 17 for designator "-D" are deemed exempt from Annex A testing. The heat input envelope indicated by the designator "-D" is 30 kJ/in [1.2 kJ/mm] to 80 kJ/in [3.1 kJ/mm] for electrodes <3/32 in [2.4 mm], and 40 kJ/in 1.6 kJ/mm] to 80 kJ/in [3.1 kJ/mm] for electrodes 3/32 in [2.4 mm] and over. Annex A has a 30 kJ/in–80 kJ/in [1.2 kJ/mm–3.1 kJ/mm] heat input range (unless tested at alternate limits), regardless of electrode diameter. The more restrictive range must be used in production.

C-6.3.6 Lowest Anticipated Service Temperature Applications. The use of a testing temperature not more than 20°F [10°C] higher than the LAST is to adjust for the effect of loading rate. The Engineer must specify the LAST when this is less than +50°F [+10°C]. This provision applies only to Demand Critical welds [see 1.2.1(10), 3.5]. For example, if LAST is +5°F [–15°C], then the testing temperature should be no lower than +25°F [–5°C].

C-6.3.8.1 Alternative to Production Lot Testing. Mechanical properties of weld metal vary in part due to variation in raw materials and production practices in the manufacture of filler metals and fluxes. Testing of each production lot provides a relatively high level of assurance that production variances are in control but such lot testing of consumables is expensive and historically has caused interruption in the availability of useable product. Filler metals are commonly produced using quality systems to provide assurances of product consistency. Certification to recognized quality management standards provides a level of assurance that production processes are in control. Once the consistent capability to achieve the required mechanical properties is established, certification to one of the listed quality system criteria is considered to provide an adequate level of assurance that consumables furnished are manufactured consistently with classification tested materials. This requirement is similar to the controls used in the welding code for bridges in the fabrication of fracture critical members.

The requirement for three different lots of filler metals to be tested is a measure of production consistency.

Certificates of Conformance or other test data from three different lots of material, as tested by the filler metal manufacturer, will satisfy this requirement, and should be retained by the filler metal manufacturer, and made available to the Contractor upon request. The Contractor should be certain that such documentation is available.

C-6.3.8.2 Exceptions. SMAW performed with either E7018 or E8018 electrodes, or GMAW performed with solid electrodes, routinely deposit welds with these mechanical properties and therefore, it is not required to perform the tests required by 6.3.8 for these process/filler metals.

C-6.4 FCAW Electrode Packaging, Storage, and Exposure

C-6.4.1 Packaging Condition. FCAW electrodes may absorb moisture when exposed to humid conditions. Electrode packaging ranges from simple cardboard boxes, to hermetically sealed foil bags. Not all packaging is capable of protecting filler metals from moisture absorption. Opened or damaged packaging is incapable of protecting filler metals from moisture absorption.

C-6.4.3 Exposure Time Limits for FCAW Electrodes. FCAW electrodes, like SMAW electrodes, can absorb moisture from the atmosphere. Such increases in moisture can increase the possibility of hydrogen assisted cracking. Because of the critical nature of welds in the SFRS, and the consequence of undetected cracks during major seismic events, this code imposes additional exposure criteria upon FCAW electrodes. AWS D1.1/D1.1M provisions for SMAW electrodes are considered adequate for this code's applications.

The rate of moisture absorption is dependent on many factors, including the design of the filler metal. These provisions are specific to the filler metal manufacturer's brand and type of electrode.

Test data suggests that 72 hours is a conservative upper limit for electrode exposure, in the absence of specific exposure data.

When welding is suspended, it is possible to store the electrode under conditions where no additional accumulation of moisture is expected to occur. When this is done, the exposure time is stopped. The time resumes when the filler metal is removed from the protective storage conditions and put back onto the welding machine.

C-6.4.4 Overexposed FCAW Electrode. When electrodes used for Demand Critical welds have exceeded the time frame as determined by tests performed in accordance with Annex E, or the 72 hours of exposure when no test data is available, whichever is applicable, the electrodes may be dried at the option of the Contractor. Alternately, the Contractor may elect to use the electrode for other than Demand Critical welds. If the Contractor elects to dry the electrode, it must be done in accordance with the electrode manufacturer's recommendations. Manufacturers have different guidelines with respect to drying of electrodes, including some electrodes for which no such drying is recommended. At a minimum, the guidelines must identify drying temperatures and times. It is possible that a specific spool or coil of electrode could be exposed, dried, exposed and subject to additional drying cycles. If this is done, the manufacturer's recommendations must state that this is permitted.

C-6.5 Maximum Interpass Temperature

C-6.5.1 Standard Maximum Interpass Temperature. The concern for maximum interpass temperature is related to the potential for slow weld cooling rates to adversely affect the mechanical properties. Refer to C-6.3.5 for discussion of cooling rates. Maximum interpass temperature needs to be measured relatively close to the weld, not more than 3 in [75 mm] away but not closer than 1 in [25 mm].

In contrast, minimum preheat temperature and minimum interpass temperature are measured at least 3 in [75 mm] from the weld to better ensure that the entire volume adjacent to the weld will be at or above the preheat and interpass temperature. The minimum preheat and interpass temperatures have evolved based on avoidance of cracking (see Figure C-6.1).

The 550°F [300°C] maximum temperature is a conservative value that is considered appropriate for steels and weld metals permitted for construction of SFRS members. Higher interpass temperatures may be acceptable, and are permitted if the higher value is established by test.

C-6.5.2 Alternative Maximum Interpass Temperature. Limitations on maximum interpass temperature are imposed because laboratory data indicates that excessive slow cooling rates may result in degradation of weld and HAZ strength and notch toughness. Temperature indicating crayons, if used, should not be marked within the weld joint area. Maximum interpass temperature shall be measured at a distance not greater than 3 in [75 mm] beyond the joint nor closer than 1 in [25 mm] (see Figure C-6.1).

To qualify the maximum interpass temperature, it will probably be necessary for the test plate to be heated to the maximum temperature after the first weld pass is applied before welding is resumed. It is permitted to heat the test plate between passes to maintain the interpass temperature that is being qualified. The test plate may cool to a lower temperature between weld passes and the test remain valid, providing the test plate is heated to at least the interpass temperature being qualified.

C-6.6 Tack Welds to Steel Backing in the Protected Zone

Tack welds for beam flange to column connections are required be made in the weld groove. However, steel backing may be welded to the column under the beam flange. Tack welds to the underside of beam flanges are prohibited. The tack welds holding weld tabs are required to be removed in accordance with 6.11.3.

It is generally preferable, but not always practical or even possible, to place tack welds inside the weld joint. By placing the tack welds within the joint, the potential for surface notches and hard heat-affected zones is minimized. The HAZ of the tack weld will be tempered by subsequent passes when placed within the joint.

Compatibility of weld metal used for tack welds within the joint must be determined (see 6.3.4). Tack welds in joints must be of a size and configuration so as to not interfere with subsequent weld passes (see AWS D1.1/D1.1M subclause 5.18). Tack welds outside weld joints may create alternate, unintended load paths, and improperly made tack welds may create stress concentrations that may be the point of crack initiation when highly strained.

C-6.7 Removal of Backing and Weld Root Treatment

Observations and studies performed after the 1994 Northridge earthquake found that left-in-place, steel (fusible) backing created notch effects at the root of the beam flange to column flange weld. Even in a weld with uniform and sound fusion in the root, the naturally resulting lack of fusion plane between one edge of the backing and the column flange created a stress concentration. Additionally, left in place backing can obscure the ultrasonic inspection detection of significant flaws that may exist at the weld root. These flaws can represent a much more severe notch condition than results from the steel backing itself.

When backing (fusible or nonfusible) is removed, backgouging to sound metal is required by this provision to provide assurance that potential root flaws within the welded joint are detected and eliminated.

It was also discovered after the Northridge earthquake, and the subsequent investigations, that the influence of left-in-place steel backing is more severe on the bottom flange, as compared to the top flange. This observation assumes that the backing is on the underside of the beam flange in both cases. When the backing is in this configuration for the bottom flange, the stress concentration occurs at the point of maximum stress in the groove weld. When similarly configured for the top flange, the notch effect due to the backing is at a lower stress point. Additionally, removal from the top flange necessitates that the removal and rewelding operations be performed through an access hole, making this a complicated operation. Thus, backing removal is not required in all cases (see 6.9). (Reference: SAC/BD-97/05, Finite Element Fracture Mechanics Investigation of Welded Beam-Column Connections, W. M. Chi, G. Deierlein, A. Ingraffea.)

C-6.8 Reinforcing Fillet Welds at Removed Weld Backing Locations

Evaluation of Northridge failures and subsequent test results has shown that the intersection of the column to beam bottom flange is an area of very high demand. A reinforcing fillet weld with a 5/16 in [8 mm] leg on the column flange helps to minimize notch effects. The fillet weld's horizontal leg may need to be larger to completely cover the weld root area. The resultant fillet weld may have unequal leg sizes, with the horizontal leg being larger.

C-6.9 Fillet Welds at Left-in-Place Steel Backing

C-6.9.1 Minimum Fillet Weld Size. In situations where backing is permitted to remain, it may be required to apply a fillet weld in order to reduce the stress concentration associated with the naturally occurring plane that is not fused to the column, created by the presence of the steel backing. When this is to be done, it is to be specified in Contract Documents per 1.2.1(6) (see Figure C-6.2).

C-6.9.2 Prohibited Welds on Left-in-Place Steel Backing. Welds that join the backing to the beam flange attract more stresses into the backing, increasing the effect of the stress concentration that occurs at the interface of the backing and column flange. This is true whether the weld is a continuous weld or a tack weld. If welds are placed in this region by accident, the welds must be removed in accordance with 6.9.3 (see Figure C-6.2).

C-6.9.3 Correction of Errors. When fillet welds are placed between the backing and the column in tee joints, the stress concentration factor associated with the naturally occurring lack of fusion plane between the backing and column is reduced. When welds are placed between the backing and the underside of the beam, more stress is conducted through the backing, and the effect of the stress concentration is magnified (see Figure C-6.2).

C-6.10 Weld Access Holes

C-6.10.1.1 Standard AWS D1.1/D1.1M Geometry. The AWS D1.1/D1.1M weld access hole geometry is acceptable for all welds on the SFRS, including Demand Critical welds, unless alternate geometries are specified by the Engineer, as required by 1.2.1(9).

Some of the AISC prequalified moment-resisting connections require that weld access holes conform to specific criteria. Nothing in this subclause should be interpreted to override the requirement to conform to the limitations and requirements of individual connection prequalifications. The Engineer is responsible for ensuring that all fabrication and detailing limitations applicable to a specific prequalified connection are specified in the Contract Documents.

C-6.10.1.2 Alternate Geometry. The access hole geometry shown in Figure 6.2 was subject to finite element analysis, physical testing, and demonstrated in the SAC project to provide improved performance for some connections. It may not be required for all connection types. At the Contractor's discretion, the alternate geometry may be used in lieu of the standard AWS D1.1/D1.1M geometry. (References: SAC/BD 00/24 Development and Improvement of Improved Details for Ductile Welded Unreinforced Flange Connections, Ricles, Mao, Lu, and Fisher.)

C-6.10.1.3 Special Geometry. For connections where the performance is dependent upon the use of a special weld access hole geometry, including situations where no access hole is to be used, the details of such access holes must be fully defined, including applicable tolerances.

C-6.10.2 Quality Requirements for Weld Access Holes. Grinding will likely be necessary if the hole is cut with a manually guided torch. If the hole is cut by a guided torch some cleanup may be needed. If the hole is drilled and sawn, additional grinding may not be needed. It is preferable to repair weld access hole imperfections by grinding. When welded repairs are required, after welding, the welded region must be ground not only to a smooth condition, but also to sound metal, to ensure no notches, cracks, or other defects exist in the area of the welded repair (see 7.7). The direction of grinding marks that meet 6.10.2.1 is not significant, and need not be controlled.

C-6.11 Weld Tabs

C-6.11.1 Minimum Weld Tab Length. Welds are sometimes specified for the full length of a connection. When joints are shown to be welded full length to intersecting pieces with small clipped corners, the minimum weld tab length may not be possible. Similar conditions exist in the corners of continuity plates adjacent to the k-area of columns.

C-6.11.2 Tack Welds Attaching Weld Tabs. Tack welds used to attach weld tabs, placed outside the weld joint, may create notches or other discontinuities that may serve as crack initiation sites. When tack welds to join weld tabs are placed within the weld joint, they become part of the final weld.

C-6.11.4 Weld Tabs for Continuity Plates. Detailing of the corners of continuity plates requires consideration of the k-area dimension, and depending on the sizes of the members involved, weld tabs at this location are not desirable, and may not be practicable (see 6.11.1 and Figure C-6.3). Under these conditions, the weld ends may be cascaded or other approaches used. Both the design and detailing need to consider these factors. Weld tabs at this location, if used, should not be removed because the removal process has the potential of causing more harm than good.

The opposite (outboard) end of the continuity plate to column flange generally permits the use of weld tabs in accordance with 6.11.1.

C-6.12 End Dams

End dams are devices arranged essentially perpendicular to a weld's centerline, intended to block the flow of molten weld metal and slag from the ends of weld joints. End dams, placed directly on the end of the groove weld joint, are prohibited because welds placed into the resultant corner are likely to contain defects. End dams prohibit molten weld metal and slag, which can injure workers below and cause fires, from dripping from the end of the weld. When placed at the end of weld tabs, any weld defects will be located outside the length of the weld joint. Placement of end dams at the end of weld tabs is permitted only when weld tabs are required to be removed. The minimum length of weld tab should be maintained when end dams are added to the end of weld tabs.

C-6.13 Welder Identification

A welder identification system is required for a number of reasons:

(1) It can serve as a means to identify sources of consistently poor quality welded joints.

(2) It may serve to enable a reduction in the percentage of NDT required for highly qualified welders who display consistent quality and conformity.

Welder identification stamps of the low-stress type are required to minimize the potential for accidental notching near the joint, which could result in stress concentrations that would affect the anticipated ductile performance of the structure.

C-6.14 Bottom Flange Welding Sequence

Examination of some fractured connections following the 1994 Northridge California earthquake revealed incomplete fusion and entrapped slag under the beam web, against the column face. This suggests that weld passes were either started or stopped at this one location, resulting in significant weld defects. Staggering the weld starts and stops on opposite sides of the beam web should reduce this problem, provided proper weld cleaning is performed after each weld pass is deposited. The direction of weld travel is not controlled by this provision.

C-6.15 Protected Zone

C-6.15.1 Attachments and Welds. Because of the desire to avoid stress concentrations that could lead to fracture in regions of high plastic strain, both this code and AISC Seismic Provisions include a prohibition on placement of welded attachments in the Protected Zone. Such a fracture occurred in a moment connection test with a composite floor slab at the location of a welded shear connector. The same researchers found that puddle welds in this region were not a concern, and hence, these welds are permitted. This code has defined a region where these prohibitions and other special procedures are to occur as the "Protected Zone." (Reference: See SAC/BD-00/24, Development of Improved Details for Ductile Welded Unreinforced Flange Connections," by J. M. Ricles, C. Mao, L. W. Lu, and J. Fisher.)

C-6.15.2 Erection Aids. There may be some instances where erection aids are required to be placed in the Protected Zones. Additionally, attachments to meet OSHA safety requirements may be necessary. In these and other such cases, erection aids and attachments to the Protected Zone must be approved by the Engineer to ensure that they will not result in stress concentrations that could cause a fracture in a seismic event. If erection aids are required to be placed within the Protected Zone, it may be necessary to remove the erection aid afterwards, and the surfaces of the Protected Zone may need to be prepared by grinding to remove any notch effects. Good welding practices, including proper preheat, should be used when erection aids are attached.

C-6.15.4.1 Grinding. Gouges and notches can act as stress raisers, and points for crack initiation, particularly in regions such as the Protected Zone. Stress concentrations that are perpendicular to the direction of applied stress are more severe than those parallel to the applied stress. This provision assumes that the direction of applied stress is parallel to the member axis. This assumption has been made in that shop drawings will rarely show the direction of applied stress, yet the member axis is clear to anyone working with the steel. When repairs are made by grinding, the slope of the repair, in the direction of the axis of the member, is required to be less steep (e.g., 1:5) as compared to the situation where the slope is perpendicular to the member axis (1:2.5).

C-6.15.4.2 Repair Welding of Gouges and Notches. It is important to ensure that the welded repair does not contain defects. Repairs are commonly made under conditions of higher restraint, and thus more preheat is required. MT is specified to ensure there are no surface breaking cracks in the completed repair weld. The provisions for gradual transition of 6.15.4.1 still apply. The slope control applies to either a depression (as is always the case in 6.15.4.1, and may be the case for an underfilled weld repair—allowed by this provision to be up to 1/16 in [1.5 mm]), or may be a protrusion, or "mound," that is above the surface of the steel. The WPS may be a prequalified WPS, and need not utilize a prequalified joint detail, providing the repair cavity geometry provides adequate access for welding.

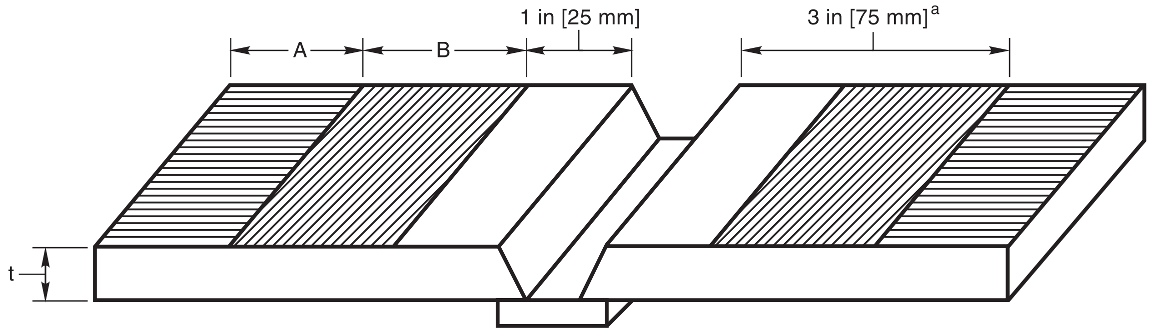
C6.15.4.3 D1.1/D1.1M subclause 5.26.3 specifies conditions where the Engineer must approve repair procedures. D1.1/D1.1M subclause 5.15 specifies repair requirements.

C-6.16 Tack Welding Requirements

C-6.16.1 Preheat. Tack welding is required to be performed by qualified personnel using approved WPSs. The preheat for tack welding is required to be in accordance with the approved WPS. The WPS for tack welding may be different than the WPS to complete or weld the required joint. Tack welds are generally small and will create heat-affected zones of proportionate sizes. The HAZ may be harder than the adjacent base metal, depending on weld cooling rate and base metal composition. Tack welds may also create mechanical notches. The welding process or electrode used for tack welding may be different than that used for the final welding, and therefore the preheat requirement for tack welding may be different.

C-6.16.2 Placement of Tack Welds. By placing the tack welds within the joint, the potential for surface notches and hard heat-affected zones is minimized. The tack weld HAZ will be tempered by subsequent passes when placed within the joint. In the Protected Zone it is desirable not to have any unnecessary hard spots or mechanical notches because this zone is expected to be capable of deforming in an inelastic manner. Thus, tack welds in the Protected Zone should be placed such that they will subsequently be covered by a weld. Subsequent weld passes will temper the HAZ of tack welds.

C-6.16.3 Removal of Improperly Placed Tack Welds. If tack welds are inadvertently made in the Protected Zone, the tack welds are required to be completely removed and the base metal ground smooth and flush.



[a] Minimum preheat and minimum interpass temperature to be measured at Location A, i.e., a minimum of 3 in [75 mm] or t, whichever is greater, away from the joint.

Note: Maximum interpass temperature to be measured at Location B, i.e., between 1 in and 3 in [25 mm and 75 mm] from the joint.

Figure C-6.1—Measurement of Preheat and Interpass Temperature (see C-6.5.1)

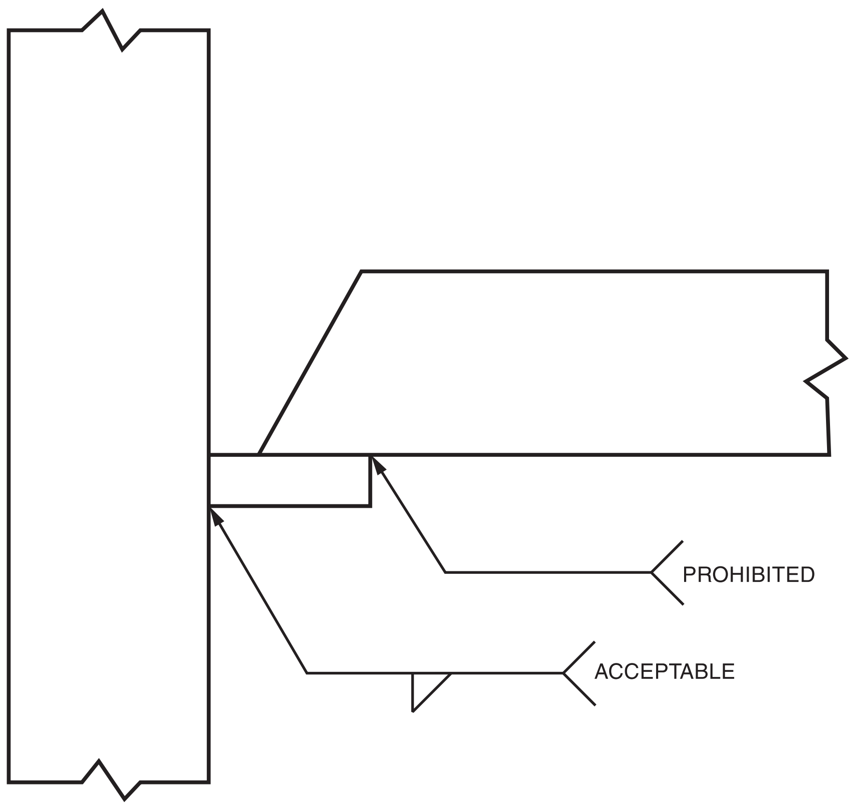
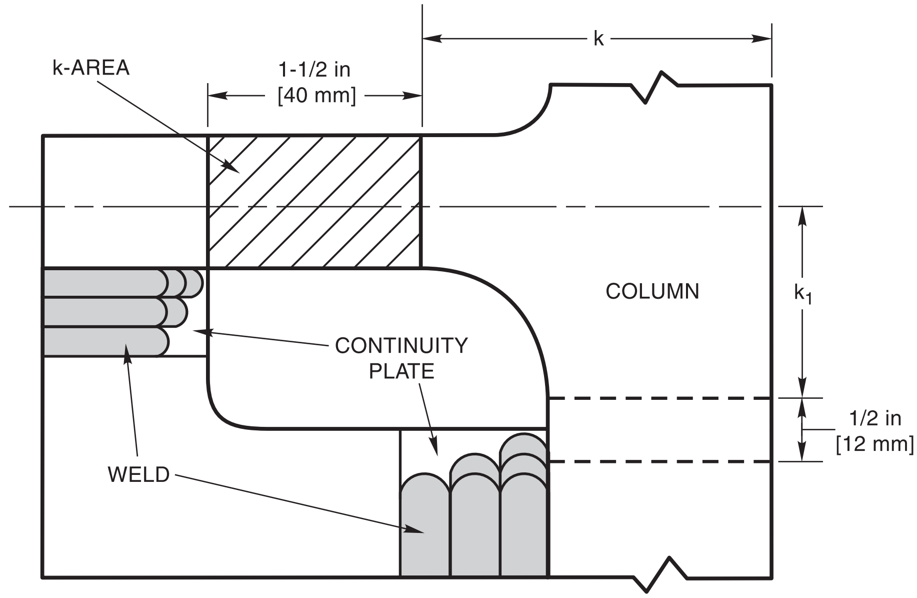
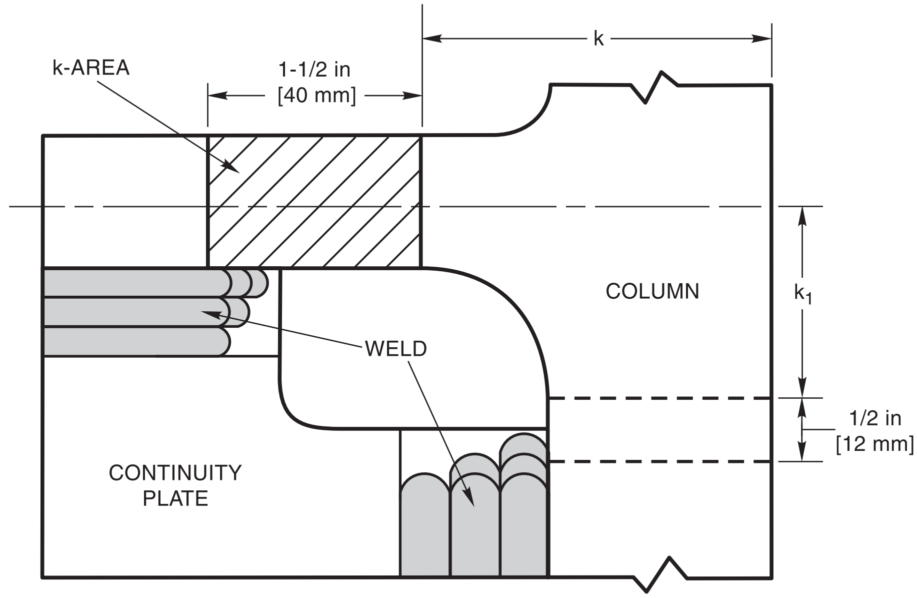


Figure C-6.2—Beam Flange to Column—Fillet Welds at Left-in-Place Steel Backing (see C-6.9.1, C-6.9.2, C-6.9.3)



(A) ACCEPTABLE

Note: Curved cope shown, straight cope is acceptable.



(B) NOT RECOMMENDED

Figure C-6.3—Continuity Plate Copes without Weld Tabs (see 6.11.4 and C-6.11.4)

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C-7. Inspection

C-7.1 Inspection Task Assignment

Quality Assurance (QA) consists of those inspection services to be performed by an agency or firm other than the Contractor. QA is performed at the prerogative of the Owner and may be mandated by the building code. QA includes monitoring of the performance of the Contractor in implementing the Contractor's QC program, ensuring that designated QC functions are performed properly by the Contractor on a routine basis. To ensure compliance, QA may also include performance of specific inspection tasks that may be similarly included in the Contractor's QC plan, including performance of nondestructive testing. Quality assurance is termed "verification inspection" in AWS D1.1/D1.1M.

Quality Control (QC) includes those functions to be performed by the Contractor to ensure that the material and workmanship of construction meet the quality requirements. QC includes inspection and testing of fabrication and erection as defined by AWS D1.1/D1.1M, unless otherwise provided for in the Quality Assurance Plan or the Contract Documents. Fabrication and erection inspection include routine welding inspection items such as personnel control, material control, preheat measurement, monitoring of welding procedures, and visual inspection. Quality control is termed "Contractor's Inspection" in AWS D1.1/D1.1M.

The Engineer is required by 1.2.1(13) and 3.4 to provide the QAP as part of the Contract Documents (see C-1.2.1 Item 13). The AISC Seismic Provisions, Appendix Q specifies the minimum requirements for a QAP as applied to welded steel construction in the SFRS. It may be appropriate to adjust these requirements based on the skill and practices of the parties involved. It is essential that the Contract Documents define these requirements.

C-7.2 Inspector Qualifications

C-7.2.1 QA Welding Inspector Qualifications. The inspector should be familiar with this code and AWS D1.1/D1.1M, *Structural Welding Code—Steel*.

C-7.2.4 UT Technicians. Ultrasonic technicians are typically certified by the employer in accordance with ASNT guidelines (SNT-TC-1A). Requirements for Level II certification can vary significantly between organizations, and ASNT Level III technicians are not required to perform a hands-on practical test, therefore Annex F provides a rigorous qualification appropriate for this work. Annex F requires a practical examination using weld mockups with known flaws with an evaluation procedure similar to API RP 2X for offshore structures.

Research and SAC/FEMA studies have shown a wide variation of ultrasonic testing (UT) personnel skills for flaw detection using current AWS D1.1/D1.1M Part F procedures. This Appendix provides a practical examination to determine the UT technician's ability using mockups of joints similar to project conditions. It is anticipated that all UT technicians would, as a minimum, be qualified for AWS D1.1/D1.1M Part F procedures for Flaw Detection. It is recommended that third party organizations be used to conduct examinations of UT technicians. The mockups with representative flaws, used for examination, are expensive and difficult to fabricate. Third party examination could provide objective, comparable, and consistent testing with potential to use same mockup samples for many examinees.

C-7.3 Quality Assurance Agency Written Practice

QA Agencies should have internal procedures (Written Practices) that document how the Agency performs and documents inspection and testing in accordance with ASTM E 329, *Specification for Agencies Engaged in the Testing and/or Inspection of Materials Used in Construction*.

C-7.4 Wide-Flange k-Area Inspection

See C-4.1. This k-area cracking has been found to manifest itself in a delayed manner. Cracking of the base metal typically occurs 24 hours to 48 hours after welding. The cracks generally, but not always, penetrate the thickness of the base metal. For doubler plates, where welding in the k-area is performed, MT in the k-area should be performed on the side of the member web opposite the weld location, and at the end of the weld. If both sides of the member web receive doubler plates in the k-area, MT of the member web should be performed after welding of one side, prior to welding of the opposite side.

C-7.5 Lamellar Tearing

Lamellar tearing is the separation (tearing) of base metal along planes parallel to rolled surface of a member. The tearing is the result of decohesion of "weak planes," usually associated with elongated "stringer" type inclusions. If and when lamellar tears occur, they generally are the result of the contraction of large weld metal deposits under conditions of high restraint in the through thickness (short transverse) direction of the base metal. Planes of near-surface stringer inclusions reduce the effective strain-resisting thickness of the base metal. Lamellar tears characteristically exhibit a "stair-step" appearance, as the crack propagates by decohesion of inclusion and metal, in the rolling direction; and by ductile shear from inclusion plane to inclusion plane in the short transverse direction.

In general, the type, size, location, and distribution of nonmetallic inclusions govern the base metal's lamellar tearing susceptibility. Susceptibility increases with increasing inclusion density, size, and proximity to the surface where shrinkage strains develop. Typically inclusions located deeper from the surface than t/4 do not contribute to lamellar tearing susceptibility.

AISC Seismic Provisions requires UT inspection of base metal that is thicker than 1-1/2 in [40 mm], loaded in tension in the through thickness direction (due to weld shrinkage strains) in tee and corner joints, where the connected material is greater than 3/4 in [20 mm] and contains CJP groove welds. The UBC and IBC contain similar provisions. Inspection of thinner base metal loaded in the through thickness direction is typically not justified. AWS D1.1/D1.1M Table 6.2 criteria are typically applied to weld metal, not base metal. This criteria has been deliberately selected as a conservative acceptance criteria for members of the SFRS. Whether the detected discontinuities existed before welding (e.g., laminations), or whether the result of weld shrinkage strains (e.g., lamellar tearing) is immaterial in terms of this provision: all discontinuities within the applicable inspection zone are required to be accepted or rejected based upon AWS D1.1/D1.1M Table 6.2.

C-7.6 Beam Copes and Weld Access Holes

Finite element studies have shown that the stress flow near and around weld access holes is very complex, and stress levels are very high, even for properly made access holes. Notches can further amplify this stress level even higher, and can lead to cracking from the access hole. Cracking from access holes was occasionally observed in the Northridge earthquake, and was commonly observed in the Great Hanshin (Kobe) earthquake. The surface of the weld access hole must be smooth. Surface defects must be found and preferably removed by grinding (see 6.10.2). Both PT and MT are capable of detecting unacceptable surface cracks. AISC Seismic Provisions requires that at welded splices and connections, thermally cut surfaces of weld access holes be inspected when the flanges thickness exceeds 1-1/2 in [40 mm] for rolled shapes, or when the web thickness exceeds 1-1/2 in [40 mm] for built-up shapes.

C-7.10 Ultrasonic Testing

C-7.10.2 Acceptance Criteria—Flaw Detection. The use of alternative techniques other than those prescribed by AWS D1.1/D1.1M Clause 6 may provide further information regarding the size, location, and nature of embedded weld flaws. To evaluate the results of such alternative techniques, it is necessary to calibrate the equipment and techniques using standard reflectors to establish a Standard Sensitivity Level (SSL) and Disregard Level (DRL), and use these values as well as the measured length of the discontinuity to establish the acceptability of the weld.

C-7.10.3 Unacceptable Welds. The Flaw Sizing methods prescribed in Annex H may permit the acceptance of weld flaws that would otherwise be unacceptable. Weld repair procedures are based on AWS D1.1/D1.1M subclause 5.26 as well as the general requirements of this standard. The decision to accept otherwise rejectable welds using flaw sizing techniques is based on the rationale that the repair may cause more damage than the defect.

Other acceptance criteria may be considered on a case-by-case basis when all the defect parameters are known and a fracture mechanics analysis is performed. It is essential to know (1) the defect size, orientation, and type in the welded joint, with sufficient accuracy, (2) the base metal and weld metal mechanical properties, predicted with sufficient accuracy, and (3) the design stress condition with due consideration for the predicted level of residual stress level and distribution. Finally, the design stress condition relative to the predicted level of residual stress must be determined.

C-7.10.4 Left-in-Place Steel Backing. A properly made weld with left-in-place steel backing will result in a variety of UT reflections that may be misinterpreted as a weld defect. Alternately, UT signals from true weld defects may be inadvertently ignored, being interpreted to be a reflection from backing (see AWS D1.1/D1.1M subclause C-6.26.12 for discussion of these issues).

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C-Annex A

WPS Heat Input Envelope Testing of Filler Metals for Demand Critical Welds

C-A1. Purpose

Heat input affects weld metal and HAZ cooling rates. Higher levels of heat input reduce cooling rates. Heat input also affects weld bead sizes, with higher levels of heat input creating larger weld beads. Both cooling rates and bead size may affect mechanical properties, and CVN toughness may be significantly changed with variations in heat input. By testing at a high and low heat input level, an "envelope" is created. Production WPSs may utilize any combination of welding variables that result in a computed heat input that is not greater than the high heat input test limit, or less than the low heat input test limit. It is expected that heat input levels between these limits will result in acceptable mechanical properties.

Tensile and elongation results obtained from welds made with heat input values between the high and low limits will likely be bracketed by the values obtained in the high and low heat input tests. CVN toughness tends to deteriorate at both high and low heat input levels; values obtained from welds made with heat input values between the high and low limits will likely be greater than the values obtained at the extremes.

The annex applies only for filler metals to be used for Demand Critical welds. Filler metals used to make other welds covered by this code are not required to be tested in accordance with this annex.

C-A2. Testing Procedure

The heat input limits listed in Table A.1 are merely suggestions and deviation from these values is possible. The suggestion was made in order to encourage some commonality between the limits selected by various filler metal manufacturers, and others that might do such testing. Some filler metals may not be capable of delivering the required mechanical properties at the suggested heat input levels; under such conditions, it is acceptable to use a tighter range of heat input values, providing the production WPS computed heat input values are within the tighter ranger. Further, if a broader range is desirable, the use of the larger range is possible in production, providing acceptable results have been obtained in testing in accordance with this annex. The use of heat input limits outside the bounds of Table A.1 are acceptable under this code, providing the higher limits have been successfully tested.

C-A3. Preheat and Interpass Temperature

Preheat and interpass temperatures may affect the mechanical properties of deposited weld metal. Testing according to this annex requires the preheat and interpass temperatures be within the prescribed ranges. These are not minimum values; the preheat and interpass temperatures are to be held within the prescribed limits shown in Table A.1. Production preheat and interpass temperatures controls are to be in accordance with this code and AWS D1.1/D1.1M, and will likely not be the same as the limits of Table A.1.

C-Table A-1

See C-A5.2.

C-A5. Welding of Test Plate

The test assembly may be restrained, or the plates preset in advance of welding in order to preclude rejection of the test assembly due to excessive warpage (see A5.3). The annex does not specify the position in which welding of the test plates is to be done. In general, from a practical viewpoint, this will typically be done in the flat position. For filler metals designed for vertical up welding, flat position welding may be difficult. It is not the intent of this annex to require qualification of filler metals in all positions in which welding will be performed. It is acceptable to use the results obtained in a flat position test to justify the use of the filler metal in the overhead position, for example.

C-A5.2 Heat Input. For the low heat input test, it will likely be necessary to allow the test plate to cool between passes in order for the test plate to achieve the prescribed interpass temperature. For the high heat input test, it may take several weld passes before the interpass temperature is achieved. This is acceptable, so long as the welding operations are not interrupted. Welding operations include cleaning of the weld, measuring interpass temperatures, etc. If welding operations are interrupted and the interpass temperature drops below the prescribed limit, welding is not permitted to resume until the interpass temperature is achieved.

Heat input is calculated by the following formula: H = 60 E I/S where H = heat input, E = arc voltage, I = current, and S = travel speed. When travel speed is measured in inches per minute [mm per minute], heat input will be expressed in units of Joules per inch [Joules per mm]. Some variation in heat input rates during the fabrication of the test plate is expected due to changes in the three variables that determine heat input. Variations in these variables are permitted so long as the total change to the computed heat input is not greater than 20% from the nominal value.

In the 2005 edition of D1.8/D1.8M, except for the root pass, a minimum of two passes per layer were required to fill the test plate. This provision was deleted from the code. Experience showed this provision was difficult or impossible to achieve with high heat input conditions. It was deemed acceptable to use single passes per layer since achieving acceptable results under such conditions is typically more difficult than when split layers are used. Production welds are to be in accordance with AWS D1.1/D1.1M limitations on weld layer thickness and split layer requirements.

C-A7. Acceptance Criteria

C-A7.1 Strength and Ductility Requirements. The tensile strength data obtained from the all weld metal tensile test specimens are all minimum values, with no maximum values specified. These criteria have been determined to be sufficient for acceptable performance of connections covered by this code. This code is not applicable to situations where filler metal of a strength level greater than that of an E80 filler metal is required. All tensile testing is done at room temperature, regardless of LAST, if specified.

C-A7.2 CVN Toughness Requirements. For applications where Contract Documents have specified a LAST for structures not normally maintained at 50°F [10°C] or higher, the testing temperature for CVN testing is required to be LAST, plus 20°F [10°C]. For other applications, testing is done at 70°F [20°C] (see 6.3.6).

C-Annex B

Intermix CVN Testing of Filler Metal Combinations (where one of the Filler Metals is FCAW-S)

C-B1. Purpose

There have been instances that even though each filler metal individually was classified as having adequate notch toughness, the mixing process during the completion weld resulted in a combined weld with reduced notch toughness. This annex is intended to ensure that unacceptable degradation does not take place.

This testing is to be performed when required by 6.3.4. The only filler metal combinations required to be tested are those where one of the two is FCAW-S. Combinations of FCAW-S with FCAW-S may be used without performing this testing. Any combinations of SMAW, FCAW-G, GMAW, SAW, or ESW may be used without performing this testing (see also C-6.3.4).

C-B2. Filler Metal Variables

Annex B and Tables B.1 and B.2 require that every combination of welding process be checked for suitability when one of the welding processes is FCAW-S. However, depending on the positioning of the weld deposited with the other process (substrate/root versus fill), not every combination of manufacturer, brand name and trademark, and diameter must be checked. For example, a single test with GMAW substrate and a specific FCAW-S electrode (AWS Classification Manufacturer, Manufacturer Brand and Trademark, and diameter) will qualify that specific FCAW-S electrode for use with GMAW electrode of the same AWS Classification, regardless of the Manufacturer, Manufacturer's Brand and Trademark, or diameter of GMAW electrode. Tables B.1 and B.2 do not require testing of every combination shown (e.g., FCAW-G and SMAW), but is applicable only when one of the two processes is FCAW-S (see C-B1).

C-B4. Welding of Test Plate

The order of deposit affects the resultant properties. If in production, FCAW-S is to be used first, and FCAW-G placed over the FCAW-S, the test plate must have FCAW-S in the root, and FCAW-G used to fill the joint. Substitution of tests performed in the opposite sequence is not permitted.

The substrate/root material may be a root pass, tack weld, or in the case of a weld repair, the original material used to make the weld joint. The fill material may be a weld process that is different from that used for tack welding, or for making the root pass. The fill material may also represent the materials used to repair defective welds.

The welding parameters used to weld the intermix test plate assembly are not restricted. Any combination of welding variables may be use, including any heat input level. It is not necessary to perform intermix testing with high and low heat input levels. It is generally advantageous to use welding parameters similar to those used for the AWS A5 specification filler metal classification test, although such parameters are not a code requirement for the intermix test.

C-B5. Test Specimens Required

While yield and tensile strength, as well as elongation, may be slightly affected by intermixing of welding processes, it is the CVN impact properties that may be more significantly affected. Accordingly, only CVN properties must be tested. When testing is being performed for welds governed by this code, but not to include Demand Critical welds, only five CVN specimens are required.

These are tested at 0°F [–18°C]. When testing is being performed for Demand Critical welds, one set of five specimens is prepared for testing at 0°F [–18°C], and another set of five is prepared for testing at 70°F [20°C]. A single set of five specimens may be used to satisfy both the 0°F [–18°C] requirement for all welds governed by this code, as well as the 70°F [20°C] requirement for Demand Critical welds, providing the testing performed at 0°F [–18°C] demonstrates an absorbed energy level no less than 40 ft·lbs [54 J]. It is possible, however, that a weld deposit may be able to achieve 40 ft·lbs [54 J] at 70°F [20°C], and 20 ft·lbs [27 J] at 0°F [–18°C], and not achieve the value of 40 ft·lbs [54 J] at 0°F [–18°C].

C-B6. CVN Specimen Location

The weld metal deposited by the second process is the material of interest. Ideally, the specimens would include only the material from the interface region and the second process material. The region that is nearest the first process weld deposit is expected to be the material that is most affected. This may be a small region. It is important that the CVN specimen be accurately located so that this small region is contained within the test region of the CVN specimen.

Due to chemistry differences between FCAW-S and other weld metals, etching of the deposit easily reveals the interface of the two weld deposits.

C-B7. Acceptance Criteria—All Welds

This testing temperature is not subject to revision by 6.3.6.

C-B8. Acceptance Criteria—Demand Critical Welds

For applications where Contract Documents have specified a LAST for structures not normally maintained at 50°F [10°C] or higher, the testing temperature for CVN testing is required to be LAST, plus 20°F [10°C]. For other applications, testing is done at 70°F [20°C] (see 6.3.6).

C-Annex D

Supplemental Welder Qualification for Restricted Access Welding

C-D1. Purpose

See 5.1.1. This test is required to be taken and passed by all welders who make Demand Critical beam-to-column flange groove welds on structures governed by this code when such welding requires that welds be made through a weld access hole. This is typically the situation of the bottom flange connection of an I-shaped beam that frames into a column. These tests are not required for any weld that is not governed by this code, is not part of the SFRS, or when welding is not performed through an access hole.

This annex is used to qualify welders for flat position groove welding. It is also used to qualify welders when nonsteel backing is used, or when open root groove welds are used. AWS D1.1/D1.1M welder qualification tests, not the tests described in this annex, are used to qualify the welder for overhead welding.

Welders previously qualified, within the time limit restrictions, using similar restricted access plate tests, should be accepted based on those tests.

C-D3. Test Plate Fabrication

C-D3.1.1 Test Plate Assembly. The basic test assembly may be assembled by an individual other than the welder being qualified. Attachment of the weld tabs must be done by the welder. Improper attachment of the weld tabs, and the resultant poor weld quality at the end of the weld, may affect the performance of the bend specimens.

C-D3.1.2 Welding Procedure Specification. The ability of the welder to control weld metal deposited at high deposition rates is an essential ingredient of this test. Typically measured in pounds of deposited metal per hour [kilograms per hour], the deposition rates can be directly determined by measuring the time it takes to deposit a weld of a known weight (mass). More frequently, deposition rates are determined by using a welding current/deposition rate chart, or a wire feed speed/deposition rate curve. For SMAW, melt off rates may be used. Any method of measurement of deposition rate is acceptable for this test.

A welder that is capable of depositing a quality weld at, for example, 10 lbs [4.5 kg] per hour, may have great difficulty making the same weld at 20 lbs [9 kg] per hour.

Deposition rates are measured based on 100% arc time, that is, only the welding time is measured. The nonwelding time (cleaning the weld, etc.) should not be considered when deposition rates are measured.

C-D3.1.4 Test Specimen Preparation. Identification of the location of the web plate is important as it is from within the 1 in [25 mm] region under the web that the center two bend specimens must be removed.

C-D3.2 Option A. A welder qualified in accordance with Option A may weld on different joint details in production (e.g., different root openings, included angles), and the WPSs may vary as well, so long as the same process is used, and the deposition rate used in production does not exceed that used in the qualification testing.

C-D3.2.2 Groove Weld Detail. The groove weld detail prescribed by this provision is used to qualify the welder for any groove weld geometry to be used in production. The groove and access hole geometry used in the test does not restrict groove and access hole geometry used in production. No other geometry may be used for the Option A test.

C-D3.2.4 Backwelding. The backgouged cavity must be restored with weld metal. The qualification test described in this annex does not require that the welder specifically demonstrate his/her skills with all the welding processes that may be used for back welding. Welder qualification to AWS D1.1/D1.1M is sufficient. Thus, for the test described in this annex, any process or procedure may be used for the backwelding operation.

C-D3.3 Option B. The backing and groove details used for Option B are not prescribed in this annex, but are rather required to be representative of the most demanding conditions that will be encountered in production. Successful qualification with a test in accordance to Option B permits the welder to weld with the same process, and same backing type, within limitations on variations in the joint details. Separate testing is required for copper, versus ceramic, versus open root joints. If steel backing is used, qualification per Option A is required.

C-D3.3.1 Backing, Root Condition, and Groove Weld Details. The test plate is intended to duplicate not only the typical conditions that will be encountered in production, but the most demanding conditions. D3.3.4 restricts the welder from welding in production joints that are larger in root opening, and tighter in the included angle, than the condition used for qualification testing. Accordingly, it is advisable to fit up the test plate with the application of tolerances that will yield the greatest production flexibility (see D3.3.4 and C-D3.3.4).

C-D3.3.3 Backgouging and Backwelding. The Supplemental Welder Qualification for Restricted Access Welding—Option B test does not require that the weld root be backgouged and backwelded before the testing required by Clause D4 is performed. However, at the Contractor's discretion, the welder has the option of backgouging the weld root. This may be desirable when root imperfections are observed or suspected. If this option is used, then the backgouging and backwelding must be performed by the welder being qualified, and such welding must be done in the overhead position.

C-D3.3.4 Option B Limitations. For joints that are backed by copper and ceramic, as well as for open joints (e.g., no backing), a more demanding condition is created when the root opening are increased, and the included angle is decreased. This provision requires that the welder demonstrate his/her skills under the hardest-to-weld root conditions. When the test plate is constructed, the restrictions of this provision should be considered (see D3.3.1 and C-D3.3.1).

C-D4. Specimen Testing

C-D4.2.1.1 Specimen Locations. The full thickness of the two bend specimens taken from the center of the weld must be taken from the 1 in [25 mm] length of the weld that was directly under the web plate. The outboard bend specimens, taken from the ends of the welds, measure the ability of the welder to make sound welds along the complete length of the weld. The side of the bend specimen nearest to the end of the weld is the region that will most likely contain weld discontinuities. It is this face of the bend specimen that is to be strained most severely during the bend test (e.g., this side will become the convex side of the bend specimen).

C-D4.2.3 UT Inspection. The use of cyclic criteria for welder qualification using UT is based upon the use of cyclic criteria when performing RT for this purpose in AWS D1.1/D1.1M subclause 4.30.3. It is not intended to reflect any need for cyclic criteria for the production weld.

C-D.5 Retesting

Welders who fail the test described in this annex are permitted to perform other welds governed by this code where this qualification test is not required.

C-Annex E

Supplemental Testing for Extended Exposure Limits for FCAW Filler Metals

C-E1. Purpose

The supplemental testing prescribed in the annex is not required to be performed for filler metals used for any process other than FCAW. Testing described in the annex is not required to support the standard 72-hour period, but is required when this time period is extended.

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C-Annex F

Supplemental Ultrasonic Technician Testing

C-F3. Test Specimens

C-F3.4 Confirmation and Categorization of Flaws. The test specimens for these examinations must be accurately characterized before being used to qualify UT technicians. A number of NDT procedures may be used, including angle RT, to fully characterize the specimen flaws. Examination by multiple qualified people can also provide assurance of specimen flaw locations.

C-F3.7 Number of Test Plates. Eight to ten different test plates, 18 in to 24 in [460 mm to 610 mm] in length, with a total of twenty or more "flaws" should provide an adequate test of ability. Typical time for these tests is 4 hours to 6 hours.

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C-Annex G

Supplemental Magnetic Particle Testing Procedures

This annex is similar to API RP2X with some simplifications. It is based on using the yoke method with dry visible particles as this is the typical method used by NDT practitioners in the building construction industry. Other techniques such as prods and more sensitive methods are typically not warranted and may only be used if approved by the Engineer.

C-G10. Yoke Placement

C-G10.2 Inspection of Discontinuities in the Longitudinal Direction. The effective area of inspection is between the yoke legs, with a lateral area of approximately 1-1/2 in [40 mm] on either side of the centerline between the yoke legs. The total length weld coverage for one position of the yoke is approximately 3 in [75 mm]. Yoke movement in 2 in [50 mm] intervals should ensure adequate overlap.

C-G10.3 Inspection of Discontinuities in the Transverse Direction. The effective area of inspection is between the yoke legs, with a 4 in [100 mm] leg spacing recommended. Sufficient overlap may be achieved by moving the yoke to a position which overlaps the last position by at least 1 in [25 mm].

C-G12. Interpretation and Evaluation of Indications

False indications are those held primarily by nonmagnetic means such as mechanical entrapment in the toe of a weld. Nonrelevant indications are those held in place by magnetic attraction, but not originating from a structural discontinuity, such as the boundary of two steels having significantly different magnetic properties or by the hardened heat-affected zone of a weld.

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C-Annex H

Flaw Sizing by Ultrasonic Testing

C-H1. Flaw Sizing

There may be specific situations where the use of highly advanced techniques for UT may be implemented, typically when the repair of a weld would be particularly difficult to access or perform, or when the repair may result in more harm to the joint than benefit. Such techniques require specialized knowledge and skills, and in some cases equipment, not commonly found among industry UT technicians.

These techniques can provide sufficient information for the application of fracture mechanics evaluation of a particular discontinuity or joint. The acceptance criteria provided was developed using a fracture mechanics approach, assuming a weld CVN toughness of 40 ft·lbf [54 J] at 70°F [21°C]. (References: FEMA 355B, State of the Art Report on Welding and Inspection, Subclause 7.4, Federal Emergency Management Agency, 2000, and SAC/BD-99/24, Weld Acceptance Criteria for Seismically-Loaded Welded Connections, W. Mohr, 1999.)

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Index

A

B

C

D

E

F

G

H

I

J

K

L

M

N

P

Q

R

S

T

U

List of AWS Documents on Structural Welding

Designation	Title
D1.1/D1.1M	*Structural Welding Code—Steel*
D1.2/D1.2M	*Structural Welding Code—Aluminum*
D1.3/D1.3M	*Structural Welding Code—Sheet Steel*
D1.4/D1.4M	*Structural Welding Code—Reinforcing Steel*
D1.5M/D1.5	*Bridge Welding Code*
D1.6/D1.6M	*Structural Welding Code—Stainless Steel*
D1.7/D1.7M	*Guide for Strengthening and Repairing Existing Structures*
D1.8/D1.8M	*Structural Welding Code—Seismic Supplement*
D1.9/D1.9M	*Structural Welding Code—Titanium*

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