

AWS D1.8/D1.8M:2021
An American National Standard

Structural Welding Code— Seismic Supplement



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An American National Standard

Approved by the
American National Standards Institute
August 16, 2021

Structural Welding Code— Seismic Supplement

4th Edition

Revises AWS D1.8/D1.8M:2016

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.



ISBN Print: 978-1-64322-206-6
ISBN PDF: 978-1-64322-207-3
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This standard is subject to revision at any time by the AWS D1 Committee on Structural Welding. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS D1 Committee on Structural Welding and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS D1 Committee on Structural Welding to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Foreword

This foreword is not part of this standard but is included for informational purposes only.

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, *Structural Welding Code—Steel*, 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.

The first edition of D1.8/D1.8M was published in 2005. The Supplement was revised in 2009 and again in 2016. This is the fourth 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 the most significant revisions from the 2016 edition:

Summary of Changes	
Clause/Table/ Figure/Annex	Modification
Clause 3	The definition of lowest anticipated service temperature (LAST) was revised, and a new definition was added; weld access hole.
Clause 4	Clause 4.3 was re-written to provide specific information about the mockup test. Figure 4.3 was revised and Figure 4.4, a new figure, was added for clarity. The macroetch specimen acceptance criteria was also revised for clarity.
Clause 6	Intermix of FCAW-S Filler Metal was revised to standardize the testing in accordance with Annex B. The Heat Input clause was modified to show the filler metals exempt from the heat input envelope testing in new Tables 6.4 and 6.5 rather than in the text. References to AWS A5.36 were removed as AWS A5.36 has been withdrawn. References to AWS A5.20 -D Designator were removed as they have been removed from AWS A5.20. Figure 6.2 was revised so that you can use it when working with small members and to prevent the slope of the access hole from being too large.
Annex B	Annex B was revised to describe an intermix test for FCAW-S over ESW welds. A new figure was also added to illustrate ESW, FCAW-S intermix test plate setup.

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

Normative Annexes. These annexes address specific subjects in the code and their requirements are mandatory requirements that supplement the code provisions.

Errata. All errata to a standard shall be published in the *Welding Journal* and posted on the AWS website (www.aws.org/standards/page/errata).

Suggestions. Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, DIL Subcommittee on Seismic Structures, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Structural Welding Code—Seismic Supplement

1. General Requirements

This clause addresses the general requirements to be applied for welded joints that are part of the Seismic Force Resisting System (SFRS).

This clause is organized as follows:

1.1 Scope and General Provisions

1.2 Standard Units of Measurement

1.3 Safety Precautions

1.4 Responsibilities

1.5 Limitations

1.6 Welding Symbols

1.1 Scope and General Provisions

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 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.

1.3 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 the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

1.4 Responsibilities

1.4.1 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 1.5)
- (2) Identification of members that comprise the Seismic Force Resisting System (SFRS) and that are subject to the provisions of this code (see Clause 3)
- (3) The location of the Protected Zone for members of the SFRS (see Clause 3)
- (4) Welds designated as "Demand Critical" and subject to specific provisions of this code (see Clause 3)
- (5) Locations where the removal of backing is required (see 6.13)
- (6) Locations where fillet welds are required when backing is permitted to remain (see 6.15)
- (7) Locations where the removal of weld tabs is required (see 6.16.3 and 6.16.4)
- (8) Locations where fillet welds are required to reinforce groove welds, or to improve connection geometry (see 6.14)
- (9) Locations of access holes and the required shape, whether standard AWS D1.1/D1.1M geometry (see 6.11.1.1), alternate geometry (see 6.11.1.2), or a special geometry designated by the Engineer (see 6.11.1.3)
- (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 Clause 3 and 6.2.2)
- (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:2020 4.3.3 and 7.20)
- (13) Quality Assurance Plan (QAP) for the project (see Clause 3 and 7.1)
- (14) Any additional provisions applicable to the specific project not governed by AWS D1.1/D1.1M or this code.

1.4.2 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.

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

1.4.2.2 Certification of Heat Input Envelope Testing. Certifications that filler metals used to make Demand Critical welds meet the Heat Input Envelope Testing requirements of 6.2.1 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.

1.4.2.3 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.

1.4.2.4 Diffusible Hydrogen Content. The Contractor shall retain documentation that the filler metals comply with the hydrogen requirements of 6.1.2, as applicable.

1.4.2.5 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.

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

1.4.2.7 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.

1.5 Limitations

This code is intended to apply to the following:

- (1) Structures made of steels with minimum specified yield strengths of 70 ksi [490 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

1.6 Welding Symbols

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

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2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply except where a specific edition is included in the citation. For dated references, subsequent amendments or revisions of the publications may not apply since the relevant requirements may have changed.

American Welding Society (AWS) Standards:

- (1) AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*
- (2) AWS A3.0, *Standard Welding Terms and Definitions*
- (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, *Welding Consumables—Procurement of Filler Metals and Fluxes*
- (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:

- (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*

(4) AISC *Steel Construction Manual*

American Society for Nondestructive Testing (ASNT) Standards:

(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):

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

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

demand critical welds. Welds designated by the Engineer in the contract documents, and required to meet specific requirements of this code.

doubler. Plate added to, and parallel with, a beam or column web to increase the strength at locations of concentrated forces.

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 [38 mm] into the web beyond the k detail dimension.¹

lowest anticipated service temperature (LAST). The lowest daily minimum temperature, or other suitable temperature, as established by the Engineer of record.

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.

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.

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.

weld access hole. An opening that permits access for welding, backgouging, or for insertion of backing.

¹ See AISC *Specification for Structural Steel Buildings* for formal definition of k detail dimension.

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4. Welded Connection Details

This clause addresses the requirements and details for specific welded connections used in the Seismic Force Resisting System (SFRS).

This clause is organized as follows:

4.1 Corner Clips of Continuity Plates and Stiffeners

4.2 Transitions in Thicknesses and Widths

4.3 Joint Details for Doublers

4.1 Corner Clips of Continuity Plates and Stiffeners

Corners of continuity plates and stiffeners shall be clipped as follows (see Figures C-4.1 and C-4.2):

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 [38 mm] beyond the published k detail dimension for the rolled shape.²

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.³

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.

4.3 Joint Details for Doublers

A prequalified WPS may be used for the welding of doublers to the webs, flanges, and fillets of hot rolled shapes using the details of Figure 4.3, provided all other requirements of Clause 5, Prequalification of WPSs, of the latest edition of AWS D1.1 are satisfied.

² See AISC 360 *Specification for Structural Steel Buildings* for formal definition of k detail dimension.

³ See the AISC *Steel Construction Manual* Part 1 for k_1 dimensions.

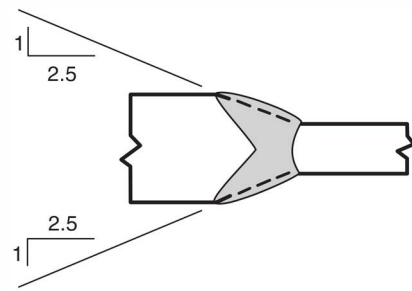
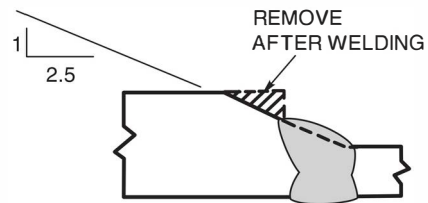
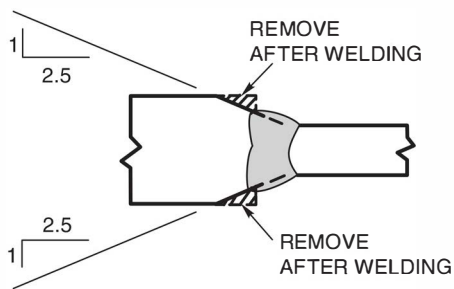
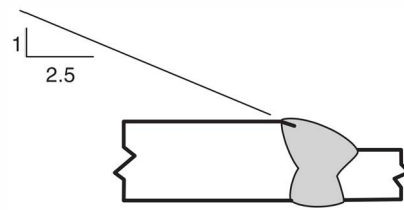
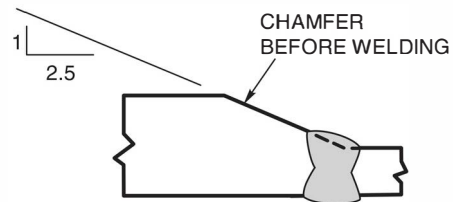
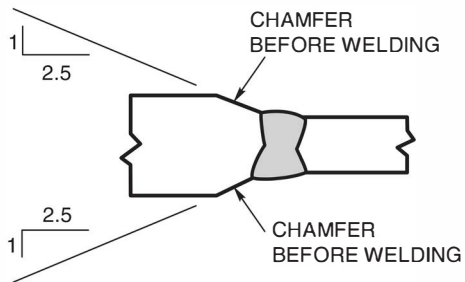
If either the production groove angle “ α ” or root opening “R” is less than permitted in Figure 4.3, the following shall be required:

- (1) Weld a mockup of the production joint with the doubler, web, and flange.
- (2) The mockup doubler weld test plate shall utilize the smallest root opening (“R”) and smallest included angle (“ α ”) to be used in production.
- (3) The thickness of the mockup doubler weld test plate shall be equal to or greater than the thickest doubler to be used in production, except that the mockup doubler thickness need not exceed 1 in [25 mm].
- (4) Prepare (3) macroetch tests approximately 4 in [100 mm] apart (see Figure 4.4). The test specimens shall be prepared with a finish suitable for macroetch examination. A suitable solution shall be used for etching to give a clear definition of the weld.

The as fit-up tolerances given for the Figure 4.3 details shall apply to the mockup dimensions when assembling the production joints.

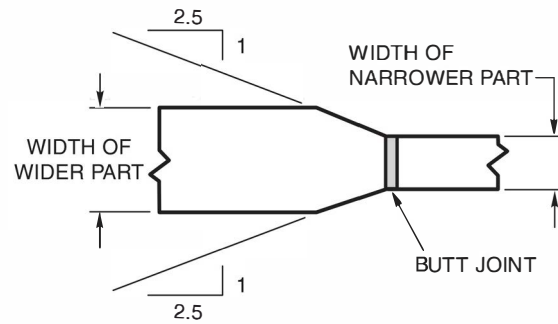
4.3.1 Macroetch Specimen Acceptance Criteria. The macroetch specimens, when inspected visually, shall conform to the following requirements:

- (1) no cracks
- (2) thorough fusion between adjacent layers of weld metal and between weld metal and base metal
- (3) thorough fusion to the root of the joint, but not necessarily beyond.

**(A) TRANSITION BY SLOPING WELD SURFACE****(B) TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING****(C) TRANSITION BY CHAMFERING THICKER PART**

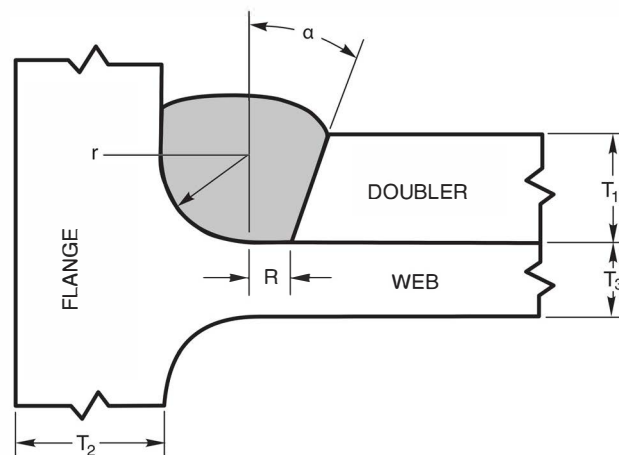
Source: Reproduced from AWS D1.1/D1.1M:2006, *Structural Welding Code—Steel*, Figure 2.2, Miami: American Welding Society.

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



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)			Root Opening Fillet Radius Groove Angle	Tolerances		Permitted Welding Position
		T ₁	T ₂	T ₃		As Detailed in [mm]	As Fit-Up in [mm]	
SMAW	Dblr	U	U	U	R = 0*	+1/16, -0 [+1.5, -0]	±1/4 [±6]	F
					r = As Rolled	N/A	As-Rolled	
					α = 20°	+10°, -0°	+10°, -5°	
GMAW FCAW	Dblr—GF	U	U	U	R = 0*	+1/16, -0 [+1.5, -0]	±1/4 [±6]	F
					r = As Rolled	N/A	As-Rolled	
					α = 30°	+10°, -0°	+10°, -5°	
SAW	Dblr—S	U	U	U	R = 0*	+1/16, -0 [+1.5, -0]	±1/4 [±6]	F
					r = As Rolled	N/A	As-Rolled	
					α = 30°	+10°, -0°	+10°, -5°	

*Root, R is the distance from the tangent of the rolled fillet to the nearest point on the doubler.

Figure 4.3—Doubler to Column Flange Joint Detail

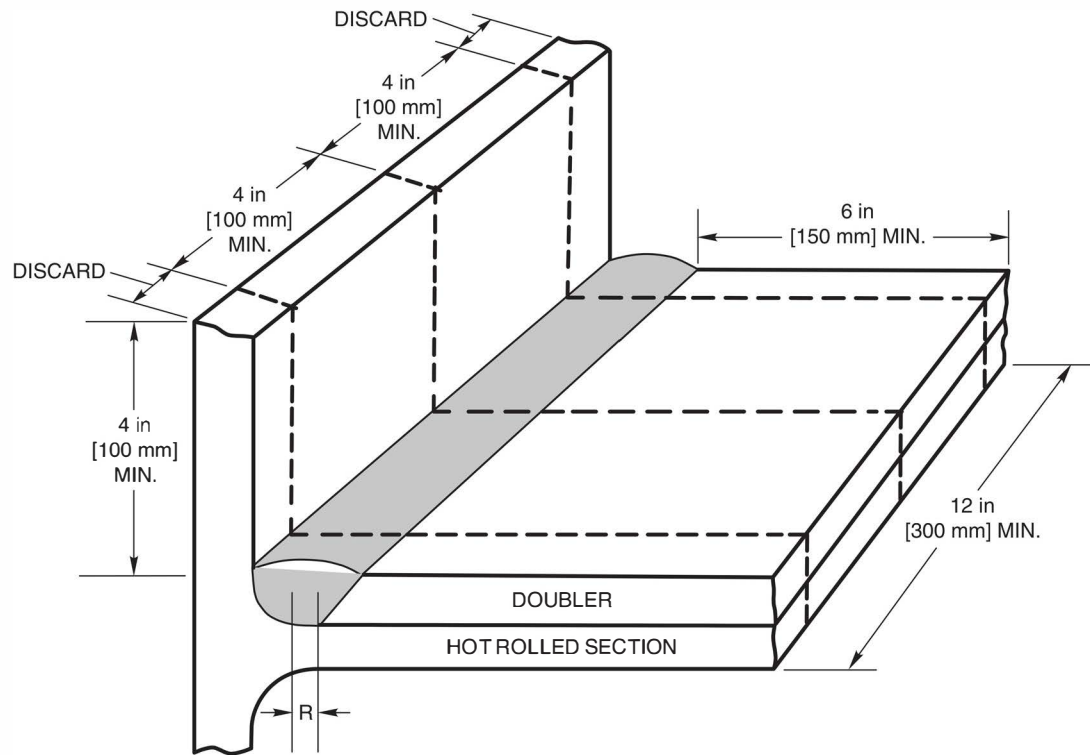


Figure 4.4—Doubler Weld Soundness Test (See 4.3)

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5. Welder Qualification

This clause addresses the requirements for the qualifications for welders that will weld Demand Critical complete joint penetration groove welds through the weld access hole in specific connections used in the Seismic Force Resisting System (SFRS).

This clause is organized as follows:

5.1 Supplemental Welder Qualification Testing

5.2 Welder Qualification Period

5.3 Welder Performance Qualification Record Information

5.1 Supplemental Welder Qualification Testing

5.1.1 Required Tests. In addition to the requirements of AWS D1.1/D1.1M:2020 Clause 6, welders shall pass the Supplemental Welder Qualification for Restricted Access Welding test as prescribed in Annex D, when the welder is required to make welds subject to all of the following requirements:

- (1) The weld is a Demand Critical complete joint penetration groove weld.
- (2) The weld joins the bottom beam flange to the column flange.
- (3) The weld in the groove 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 in the flat position 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 backing other than steel 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 test prescribed in Annex D shall remain valid for 36 months, providing the continuity requirements for process use of AWS D1.1/D1.1M:2020 6.2.3 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 test described in Annex D shall, as a minimum, provide all applicable essential variables contained in Table 6.12 of AWS D1.1/D1.1M:2020, and the following:

- (1) Type of backing, if used
- (2) Maximum root opening (if steel backing is not used)
- (3) Minimum groove angle (if steel backing is not used)
- (4) Maximum deposition rate

6. Fabrication

This clause addresses the requirements for the filler metals; weld metal; welding procedure specifications (WPSs); fabrication details, welding, and repair of specific welded joints; and specific prohibitions and repairs in the Protected Zone; as used in the Seismic Force Resisting System (SFRS).

This part contains one clause:

Part A—Filler Metal and Weld Metal

Part B—Additional Requirements for Demand Critical Filler Metal and Weld Metal

Part C—Welding Procedure Specifications

Part D—Details

Part E—Protected Zone

Part A Filler Metal and Weld Metal

This part addresses the requirements for the filler metals and weld metal used in the Seismic Force Resisting System (SFRS). Additional requirements for Demand Critical filler metal and weld metal are addressed in Part B.

This part contains one clause:

6.1 Filler Metal and Weld Metal

6.1 Filler Metal and Weld Metal

All welds governed by this code shall comply with all the requirements of 6.1. The requirements of 6.2.1, 6.2.2, 6.2.3, and 6.3.1 shall apply only to Demand Critical welds.

6.1.1 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.

6.1.2 Diffusible Hydrogen Level. All welding electrodes and electrode-flux combinations shall meet the requirements of Table 6.2.

6.1.3 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 6.1.1 and 6.1.2. Testing of filler metal samples or of production welds shall not be required.

6.1.4 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 Annex B.

Part B

Additional Requirements for Demand Critical Filler Metal and Weld Metal

This part addresses the additional requirements for the filler metals and weld metal used for welds designated as Demand Critical welds in the Seismic Force Resisting System (SFRS). Requirements for all filler metals and weld metal used on the SFRS are addressed in Part A.

This part is organized as follows:

6.2 Heat Input Envelope

6.3 Production Lot Control

6.4 FCAW Electrode Packaging, Storage, and Exposure

6.2 Heat Input Envelope

6.2.1 WPS Heat Input Envelope Testing Properties. Filler metals for Demand Critical welds shall provide the mechanical properties in Table 6.3, based upon the WPS Heat Input Envelope Testing prescribed in Annex A, except the filler metals shown in Table 6.4 shall be exempt from the testing prescribed in Annex A when LAST is equal to or greater than 50°F [10°C].

6.2.2 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 6.2.1 shall be provided:

- (1) at a test temperature not more than 20°F [11°C] above the Lowest Anticipated Service Temperature for 70 ksi [490 MPa] and 80 ksi [550 MPa] filler metals, and
- (2) at LAST for 90 ksi [620 MPa] filler metals.

The exemptions in 6.2.1 and 6.3.4 shall not apply when LAST is less than 50°F [10°C].

6.2.3 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 Production Lot Control

6.3.1 Production Lots

- (1) Production lots shall be as defined in AWS A5.01M/A5.01.
- (2) Production lots shall meet the following requirements:
 - (a) Class C3 or C4 for SMAW electrodes
 - (b) Class S3 or S4 for solid electrodes for GMAW and SAW
 - (c) Class T3 or T4 for FCAW and composite electrodes for GMAW and SAW
 - (d) Class F2 for SAW fluxes

6.3.2 Filler Metal Production Lot Testing. Each production lot of filler metal used to make Demand Critical welds shall be tested in conformance with

- (1) the applicable AWS A5 specification filler metal classification tests, and
- (2) Annex A.

6.3.3 Alternative to Filler Metal Production Lot Testing. Filler metals used to make Demand Critical welds shall be exempted from production lot testing, provided:

(1) a minimum of three different lots of material, as defined in 6.3.1, for each trade name and diameter to be used in production, are first tested in accordance with Annex A, and

(2) the filler metals have been produced by manufacturers audited and approved by one or more of the following agencies:

- (a) American Bureau of Shipping (ABS)
- (b) Lloyd's Register of Shipping
- (c) American Society of Mechanical Engineers (ASME)
- (d) U.S. Department of Defense
- (e) A quality assurance program acceptable to the Engineer

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

6.3.4 Testing for Exemptions to Production Lot Testing

(1) For LAST greater than or equal to 50°F [10°C], filler metals listed in Table 6.4 shall be exempted from production lot testing when the CVN toughness of the weld metal deposited with the electrode equals or exceeds 20 ft-lbf [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.

(2) For LAST less than 50°F [10°C], the tests to support exemption from production lot testing for filler metals listed in Table 6.4 shall be conducted at a temperature not more than 20°F [11°C] above LAST for 70 ksi [490 MPa] and 80 ksi [550 MPa] filler metals, and at a temperature not more than LAST for 90 ksi [620 MPa] filler metals.

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 6.1.2. 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 as recommended by the manufacturer is permitted.

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 prescribed 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.

Part C

Welding Procedure Specifications

This part addresses the requirements for the welding procedure specifications used to make welds in the Seismic Force Resisting System (SFRS).

This part is organized as follows:

6.5 Welding Processes

6.6 Welding Procedure Specifications (WPSs)

6.7 Maximum Interpass Temperature

6.8 Heat Input

6.9 Bottom Flange Welding Sequence

6.10 Welder Identification

6.5 Welding Processes

6.5.1 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.

6.5.2 Other Processes for Demand Critical Welds. 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 described in AISC 341;
- (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 341;
- (4) The process is approved by the Engineer.

6.6 Welding Procedure Specifications (WPSs)

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

6.6.2 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) One or more combinations of variables that produce heat input limits listed in 6.8.1.

6.6.3 Air Velocity Limits

6.6.3.1 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.

6.6.3.2 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.

6.7 Maximum Interpass Temperature

6.7.1 Standard Maximum Interpass Temperature. The maximum interpass temperature shall not exceed 550°F [288°C], unless an alternate value is qualified in accordance with 6.7.2. The maximum interpass temperature shall be measured at a distance of 1 in to 3 in [25 mm to 75 mm] from the joint.

6.7.2 Alternative Maximum Interpass Temperature. The temperature limit of 6.7.1 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 6.1.1 and 6.2.1, as applicable. The HAZ CVN toughness shall be tested in accordance with AWS D1.1/D1.1M:2020 Clause 6, Qualification, and shall meet the minimum requirement shown in Table 6.1 of this code 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.

6.8 Heat Input

6.8.1 Heat Input Limits. Heat input limits on WPSs for Demand Critical welds shall be within the heat input range qualified by testing in accordance with Annex A.

6.9 Bottom Flange Welding Sequence

Complete joint penetration groove welds of beam bottom flanges to column flanges, or of beam bottom flanges 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.

6.10 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.

Part D Details

This part addresses the requirements for the fabrication details, welding, and repair of specific welded joints, as used in the Seismic Force Resisting System (SFRS).

This part is organized as follows:

6.11 Weld Access Holes

6.12 Tack Welding Requirements

6.13 Removal of Backing and Weld Root Treatment

6.14 Reinforcing Fillet Welds at Removed Weld Backing Locations

6.15 Fillet Welds at Left-in-Place Steel Backing

6.16 Weld Tabs

6.17 End Dams

6.11 Weld Access Holes

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

6.11.1 Shape

6.11.1.1 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, Figure 6.2 may be used.

6.11.1.2 Alternate Geometry. When alternate geometry is required by Contract Documents for beam-to-column moment connections, the weld access hole shall comply with Figure 6.2.

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

6.11.2 Quality Requirements for Weld Access Holes

6.11.2.1 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.

6.11.2.2 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.

6.11.2.3 Repair of Notches by Welding. Notches deeper than those that can be repaired by grinding (as defined in 6.11.2.2) 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 [66°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.

6.12 Tack Welding Requirements

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

6.12.2 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.

6.12.3 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 flange to column flange welds.

6.12.4 Removal of Improperly Placed Tack Welds. Improperly placed tack welds shall be removed by grinding. Gouges or notches shall be repaired in accordance with 6.18.5.2.

6.13 Removal of Backing and Weld Root Treatment

When fusible (steel) backing is required to be removed, removal shall be by air carbon arc gouging (CAG), plasma arc gouging (PAG), grinding, chipping, or other thermal cutting processes. 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 back welding 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.

6.14 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 back weld and base metal is ground smooth after removal of backing, the fillet need not extend to the base metal. See Figure 6.1.

6.15 Fillet Welds at Left-in-Place Steel Backing

6.15.1 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].

6.15.2 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.

6.16 Weld Tabs

6.16.1 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.

6.16.2 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 6.12.

6.16.3 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 gouging (CAG), 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 μ in [13 μ m]. 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.

6.16.4 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.

6.17 End Dams

6.17.1 Material. End dams may be metallic or nonmetallic.

6.17.2 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).

Part E *Protected Zone*

This part addresses the requirements for specific prohibitions of attachments and erection aids, and for repairs in the Protected Zone; as used in the Seismic Force Resisting System (SFRS).

This part contains one clause:

6.18 Protected Zone

6.18 Protected Zone

6.18.1 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.

6.18.2 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.

6.18.3 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 other thermal cutting processes. The process shall be controlled to minimize errant gouging. After removal, the area shall be ground smooth and shall be free of defects.

6.18.4 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 6.18.5.

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

6.18.5.1 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.

6.18.5.2 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 with an applicable WPS. Preheat shall be in accordance with AWS D1.1/D1.1M, but shall not be less than 150°F [66°C]. Electrodes shall comply with 6.1. 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 at least the base metal thickness less 1/16 in [1.5 mm].

6.18.6 Repair of Mislocated Holes. Where the Engineer requires welded restoration of holes in the Protected Zone, a procedure shall be developed by the Contractor and approved by the Engineer. The procedure shall include an appropriate WPS with a minimum preheat of 150°F [66°C], a requirement to grind the weld reinforcement surface flush as defined in AWS D1.1/D1.1M:2020 Clause 7, and verification of the soundness of the weld using both magnetic particle testing and ultrasonic testing.

6.18.7 Repair of Mislocated Stud Welds. Mislocated studs in the Protected Zone shall be cut off and ground flush.

6.18.8 Repair of Mislocated Screws and Shot Pins. Where mislocated pins or screws are required by the Engineer to be repaired by welding, a procedure shall be developed by the Contractor and approved by the Engineer. The procedure shall include an appropriate WPS with a minimum preheat of 150°F [66°C], and shall include the shape of the excavation to be restored by welding. Grinding or gouging shall be performed to the depth of the pin or screw. The welded surface shall be ground flush. The weld soundness shall be verified by both magnetic particle testing and ultrasonic testing.

Table 6.1
Filler Metal Mechanical Property Requirements (see 6.1.1)

Property	Classification Strength Levels		
	70 ksi [490 MPa]	80 ksi [550 MPa]	90 ksi [620 MPa]
Yield Strength, ksi [MPa] ^a	58 [400] min.	68 [470] min.	78 [540] min.
Tensile Strength, ksi [MPa]	70 [490] min.	80 [550] min.	90 [620] min.
Elongation (%)	22 min.	19 min.	17 min.
CVN Toughness, ft-lbf [J] ^b	20 [27] min. @ 0°F [–18°C]	20 [27] min. @ 0°F [–18°C]	25 [34] min. @ –20°F [–29°C]

^a 0.2% offset method.

^b Filler metals classified as meeting the required absorbed energy at a temperature lower than the required test temperature also meet this requirement.

Table 6.2
Diffusible Hydrogen Testing Requirements (see 6.1.2)

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

^a These optional tests may be used in lieu of the standard tests, at the option of the Contractor.

^b These filler metals are exempt from any measurement to determine hydrogen content.

^c There is no standard test for measuring diffusible hydrogen for these filler metals.

Table 6.3
Mechanical Property Requirements for Demand Critical Welds (see 6.2.1)

Property	Classification Strength Levels		
	70 ksi [490 MPa]	80 ksi [550 MPa]	90 ksi [620 MPa]
Yield Strength, ksi [MPa] ^a	58 [400] min.	68 [470] min.	78 [540] min.
Tensile Strength, ksi [MPa]	70 [490] min.	80 [550] min.	90 [620] min.
Elongation (%)	22 min.	19 min.	17 min.
CVN Toughness, ft-lbf [J] ^{b,c}	40 [54] min. @ 70°F [21°C]	40 [54] min. @ 70°F [21°C]	40 [54] min. @ 50°F [10°C]

^a 0.2% offset method.

^b For LAST of 50°F [10°C]. For LAST less than 50°F [10°C], see 6.2.2.

^c Tests conducted in accordance with Annex A meeting 40 ft-lbf [54 J] min. at a temperature lower than the required test temperature also meet this requirement.

Table 6.4
Filler Metal Classifications Exempt From Heat Input Envelope Testing
When LAST ≥ 50°F [10°C] (see 6.2.1)

AWS Filler Metal Specification		Process	Classification Strength		Electrode Classification	
U.S. Customary Units	SI Units		ksi	MPa	U.S. Customary Units	SI Units
A5.1	A5.1M	SMAW	70	490	E7018 E7018-1	E4918 E4918-1
A5.5	A5.5M	SMAW	70 80	490 550	E7018-C3L E8018-C3	E4918-C3L E5518-C3
A5.18	A5.18M	GMAW	70	490	ER70S-X	ER49S-X
A5.28	A5.28M	GMAW	80	550	ER80S-NiX	ER55S-NiX

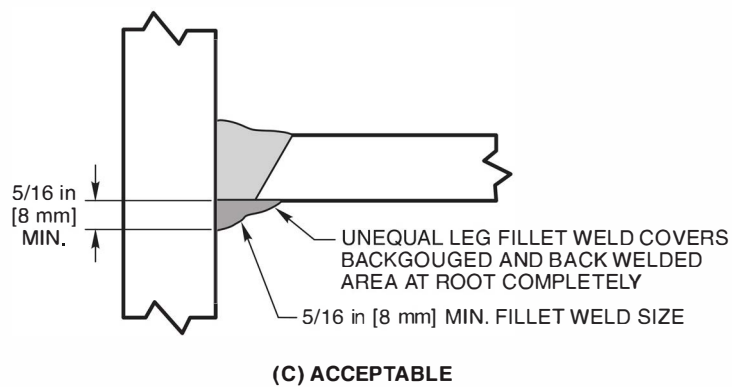
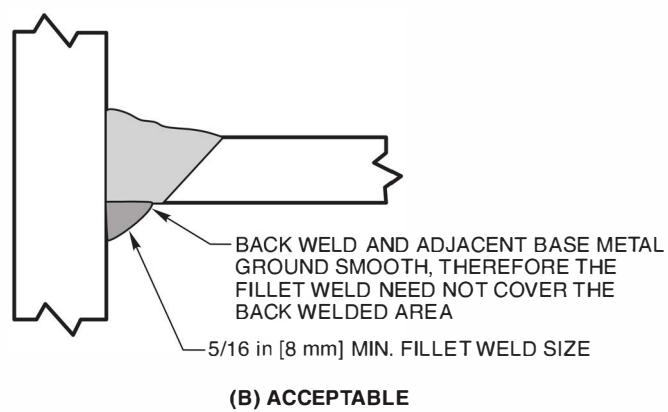
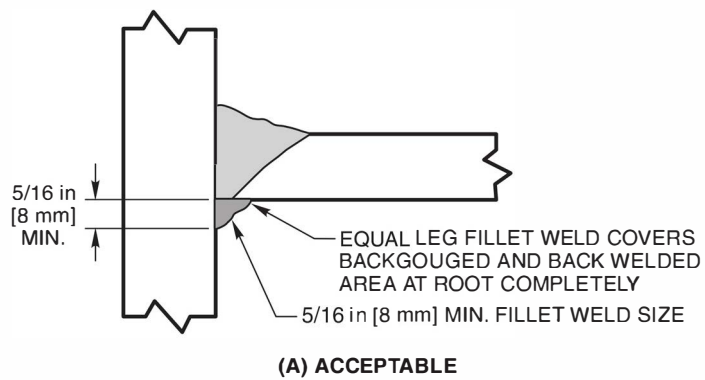
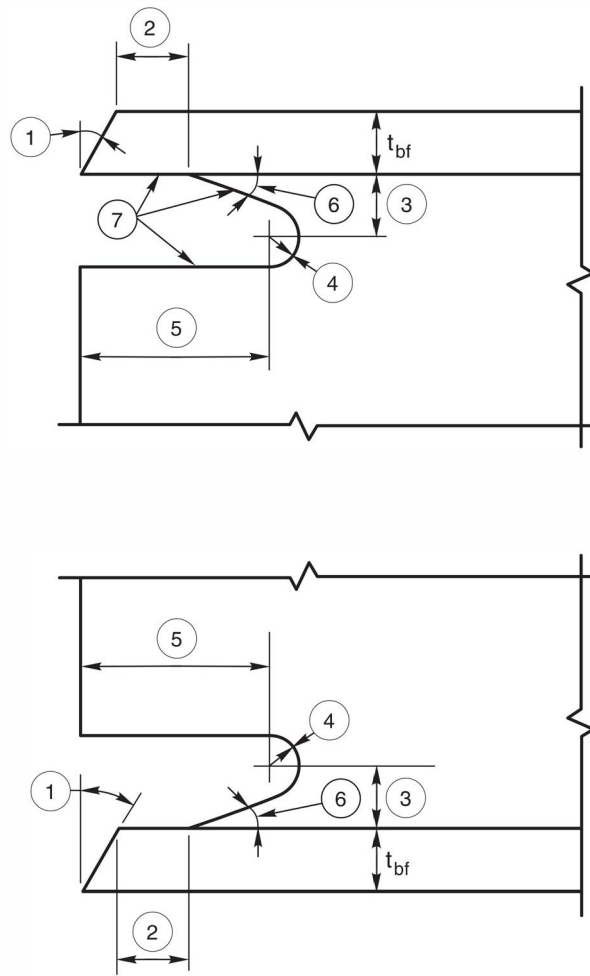
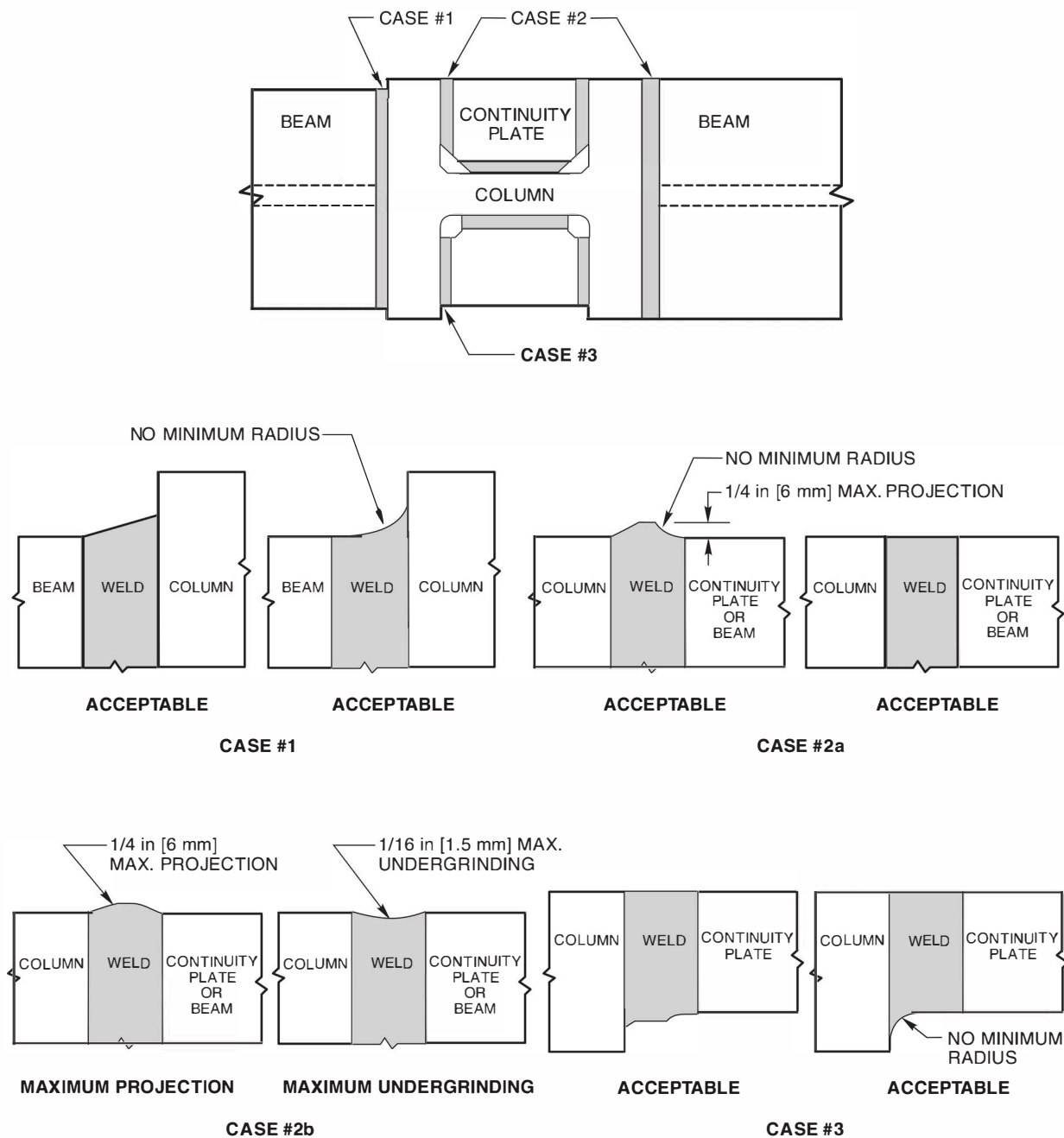


Figure 6.1—Reinforcing Fillet Weld Requirements (see 6.14)



Item	Description	As Detailed	As Fabricated
1	Groove Angle	As required for WPS	
2	Distance from as-detailed weld toe to intersection of weld access hole and beam flange	t_{bf} or 1/2 in [12 mm], whichever is greater	+0.5 t_{bf} -0.25 t_{bf}
3	Distance from inner surface of beam flange to working point of weld access hole radius	For $t_{bf} \leq 1$ in [25 mm], 3/4 in [20 mm] For $t_{bf} > 1$ in [25 mm], 0.75 t_{bf} minimum, t_{bf} maximum	+1/4 in [6 mm] -0
4	Radius of curve	3/8 in [10 mm], minimum	+unlimited not less than 3/8 in [10 mm]
5	Distance from end of web member to working point of weld access hole radius	3 t_{bf} minimum	$\pm 1/2$ in [12 mm]
6	Angle at intersection of weld access hole and beam flange	25° maximum	+5° -unlimited
7	Surface roughness	see 6.11.2.1	

Figure 6.2—Alternate Geometry—Beam Flange Weld Access Hole Detail (see 6.11.1.2)



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 6.16.3)

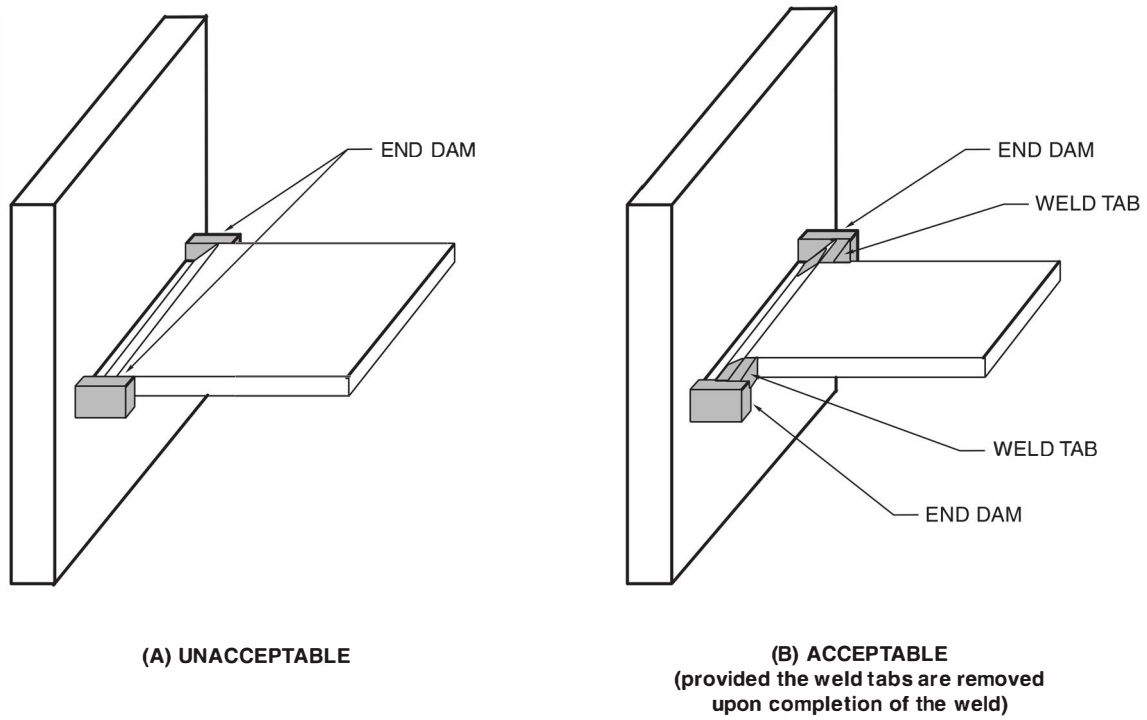


Figure 6.4—Acceptable and Unacceptable Use of End Dams (see 6.17.2)

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7. Inspection

This clause addresses the requirements for Quality Assurance Plans, welding inspector and NDT technician qualifications, inspection requirements, nondestructive testing requirements, and acceptance criteria for the Seismic Force Resisting System (SFRS).

This clause is organized as follows:

7.1 Inspection Task Assignment

7.2 Inspector Qualifications

7.3 Quality Assurance Agency Written Practice

7.4 Wide-Flange k-Area Inspection

7.5 Lamellar Tearing

7.6 Beam Copes and Weld Access Holes

7.7 Repaired Weld Access Holes in the Protected Zone

7.8 NDT of Repaired Tab Removal Sites

7.9 Magnetic Particle Testing Requirements

7.10 Ultrasonic Testing

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, *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 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 conducted, or

(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 Standards Association (CSA) Standard W178.2, *Certification of Welding Inspectors*. 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 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, or otherwise qualified under the provisions of AWS D1.1/D1.1M:2020 8.1.4, and to the satisfaction of the Contractor's QC program.

7.2.4 UT Technicians. Ultrasonic testing (UT) 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 doublers, 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:2020 Table 8.2.

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 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 MT or PT.

7.8 NDT of Repaired Tab Removal Sites

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

7.9 Magnetic Particle Testing Requirements

Magnetic particle testing (MT) 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 (UT) of welds required by the Quality Assurance Plan shall be performed according to the procedures prescribed in AWS D1.1/D1.1M:2020 Clause 8, Part F, following a written procedure containing the elements prescribed in AWS D1.1/D1.1M:2020 Clause Q3 of Annex Q, UT Examination of Welds by Alternative Technique.

AWS D1.1/D1.1M:2020 Clause 8, Part F procedures shall be qualified using weld mock-ups having 1.5 mm diameter side drilled holes similar to Annex Q Figure Q.3 of AWS D1.1/D1.1M:2020.

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:2020 Clause 8, Part F shall be in accordance with AWS D1.1/D1.1M:2020 Table 8.2.

When the alternative procedures of AWS D1.1/D1.1M:2020 Annex Q, 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:2020 Table Q.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:2020 8.25.12).

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 weld root.

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Annex A (Normative)

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

This annex is part of this standard and includes mandatory elements for use with this standard.

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, as prescribed in Clause 6.2. These procedures are intended to ensure that welds deposited with filler metals tested in accordance with these procedures will be capable of providing welded joints with the required weld metal 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.

This annex is organized as follows:

A1 Testing Procedure

A2 Preheat and Interpass Temperature

A3 Test Plate Details

A4 Welding of Test Plate

A5 Test Specimens Required

A6 Acceptance Criteria

A1. 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.

A2. Preheat and Interpass Temperature

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

A3. 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 E70X [E49X] filler metals shall conform either to ASTM A36, A572 Grade 50, or A992. Plates for

qualification of E80 [E55] filler metals shall conform to either ASTM A36, A572 Grade 50, ASTM A572 Grade 65, or A913 Grade 65, at the Contractor's option. Plates for qualification of E90 [E62] filler metals shall conform to either A572 Grade 50, ASTM A572 Grade 65, A913 Grade 65, or A913 Grade 70 at the Contractor's option. Steel backing shall be of one of the six specifications and grades listed above, but need not be the same as the base material used for the qualification test plates.

A4. Welding of Test Plate

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

A4.1 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.

A4.2 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 $\pm 20\%$.

A4.3 Warpage. A completed test plate that is warped more than 5° from flat shall be discarded. Welded test assemblies shall not be straightened.

A4.4 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 [93°C to 104°C] for up to 48 hours, then cooled to room temperature, before testing.

A5. 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*.

A6. Acceptance Criteria

A6.1 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.

A6.2 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.

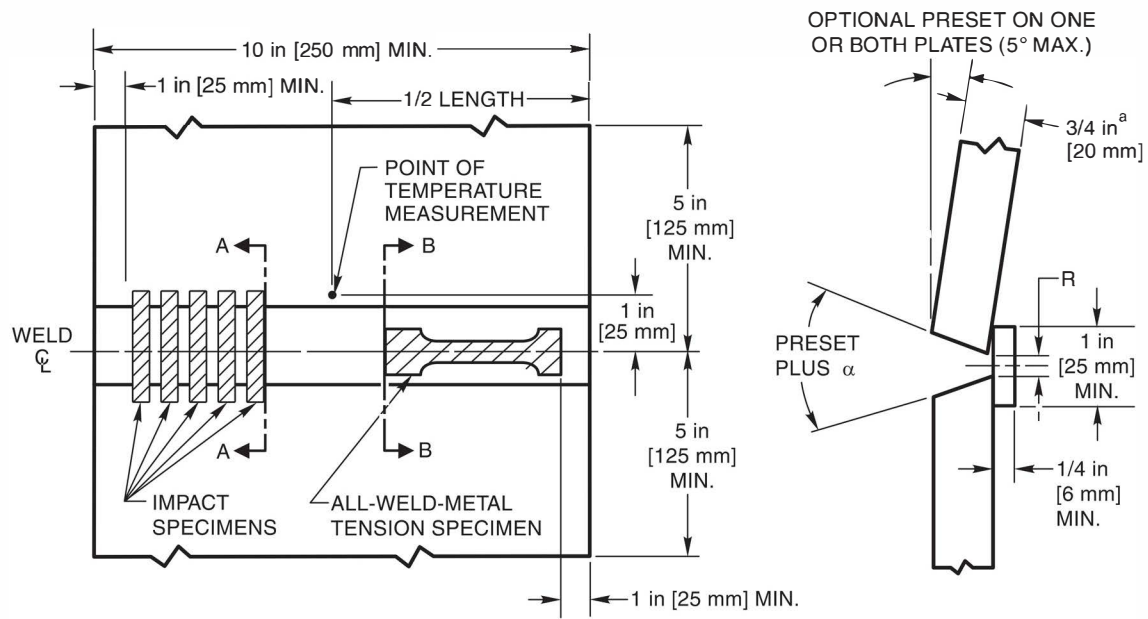
Table A.1
Heat Input Envelope Testing—Heat Input, Preheat, and Interpass Temperatures (see A2)

	Suggested Heat Input	Maximum Preheat Temperature	Maximum Interpass Temperature
Low Heat Input Test	30 kJ/in [1.2 kJ/mm]	120°F [49°C]	250°F [121°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 [121°C]	450°F [232°C]

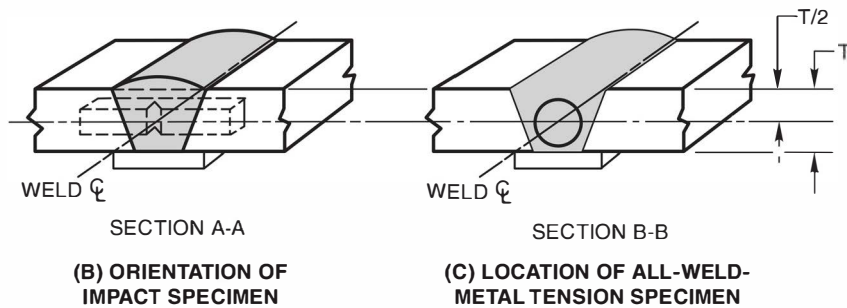
^a For the high heat input test, the test plate shall be heated to the minimum preheat, and then welding shall begin. Welding shall continue without substantial, deliberate interruption until the minimum interpass temperature is obtained. After the test plate has been heated to the minimum interpass 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 A6.1, A6.2)

Nominal Electrode Classification Strength	E70 [E49]	E80 [E55]	E90 [E62]
Minimum Yield Strength, ksi [MPa] 0.2% offset method	58 [400] min.	68 [470] min.	78 [540] min.
Minimum Tensile Strength, ksi [MPa]	70 [490] min.	80 [550] min.	90 [620] min.
Minimum Elongation (%), measured in a 2 in [50 mm] gage length	22 min.	19 min.	17 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]	40 ft-lbf [54 J] @ 50°F [10°C]
Minimum CVN Toughness when LAST is less than 50°F [10°C]	40 ft-lbf [54 J] @ LAST +20°F [11°C]	40 ft-lbf [54 J] @ LAST +20°F [11°C]	40 ft-lbf [54 J] @ LAST



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



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

^aFor SAW, test plate thickness may be 1 in [25 mm].

Figure A.1—Heat Input Envelope Test Plate (see A3, A4.1, A5)

Annex B (Normative)

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

This annex is part of this standard and includes mandatory elements for use with this standard.

This annex provides testing procedures used to determine the suitability of combining FCAW-S with other welding processes in a single joint, as prescribed in Clause 6.1.4.

This annex is organized as follows:

B1 Testing

B2 Filler Metal Variables

B3 Test Plate Details

B4 Welding of Test Plate

B5 Test Specimens Required

B6 CVN Specimen Location

B7 Acceptance Criteria—All Welds

B8 Acceptance Criteria—Demand Critical Welds

B1. Testing

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 using materials described below is required.

(1) ASTM A36, ASTM A572 Grade 50 or ASTM A992 shall be used to evaluate E70 [E49] filler metal combinations.

(2) ASTM A572 Grade 65 or ASTM A913 Grade 65 shall be used to evaluate E80 [E55] filler metal combinations.

(3) ASTM A913 Grade 70 shall be used to evaluate E90 [E62] filler metal combinations.

B3.1 Intermix with FCAW-G, SMAW, GMAW, SAW. 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 welding procedure qualification test plate may be used in accordance with 6.1.4(2).

B3.2 Intermix with ESW. The intermix test plate shall be made by welding a butt joint with ESW. The base metal for the test shall be no less than 3/4 in [20 mm] thick. Any ESW WPS may be used, except that the ESW consumables used shall be the same trade name as will be evaluated in the intermix test. After the ESW butt weld is welded, a groove not less than 1/2 in [12 mm] deep shall be machined, ground or gouged into the ESW weld. The groove shall be not less than 1/2 in [12 mm] wide at the top of the gouge, and shall have a root radius of not less than 1/4 in [6 mm] as illustrated in Figure B.3. The full thickness of the groove shall be rewelded with the FCAW-S filler metal to be evaluated in the intermix test.

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. Except for ESW substrates, 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* (see 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.4).

B7. Acceptance Criteria—All Welds

For welds using 70 ksi [490 MPa] and 80 ksi [550 MPa] filler metals governed by this code, the required CVN toughness value shall be 20 ft-lbf [27 J] at 0°F [−18°C]. For welds using 90 ksi [620 MPa] filler metals the required CVN toughness shall be 25 ft-lbf [34 J] at −20°F [−30°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-lbf [27 J] at the testing temperature. One of the three may be lower, but not lower than 5 ft-lbf [7 J] below the required absorbed energy. The average of the three shall not be less than the minimum required absorbed energy.

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·lbf [54 J] at 70°F [21°C], or at the temperature as required by 6.2.2. 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·lbf [54 J] at the testing temperature. One of the three may be lower, but not lower than 30 ft·lbf [40 J] at the testing temperature. The average of the three shall not be less than 40 ft·lbf [54 J]. For applications where LAST is below 50°F [10°C], the CVN testing temperature shall be LAST plus 20°F [11°C].

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

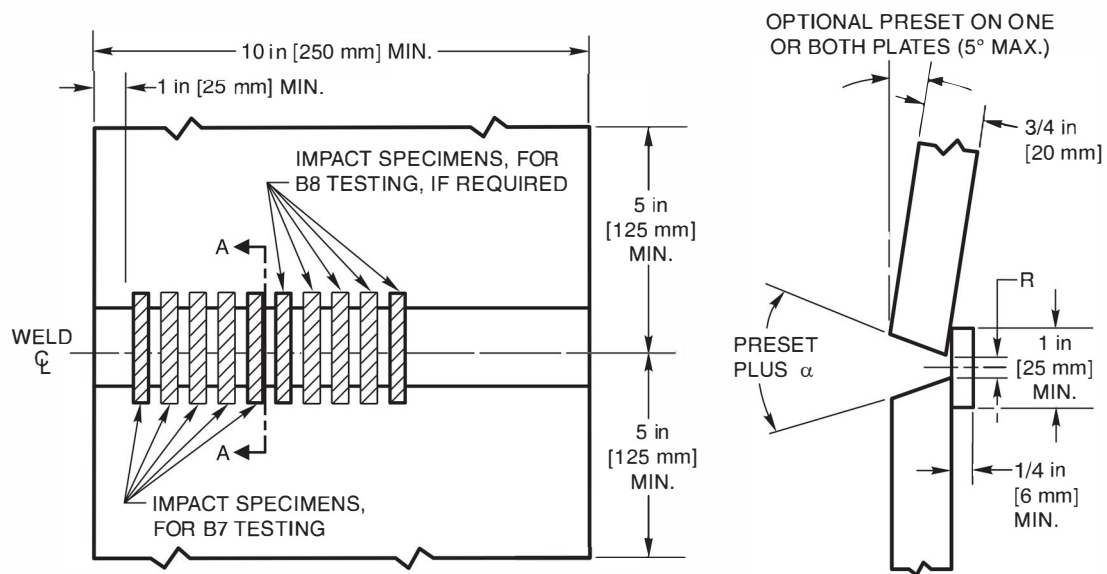
	Substrate/Root	Fill					
	FCAW-S	FCAW-S	FCAW-G	SMAW	GMAW	SAW	Other
AWS Classification	X		X	X	X	X	X
Manufacturer	X		X	X		X	X
Manufacturer's Brand and Trade Name	X		X	X		X	X
Diameter			X	X	X	X	X

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

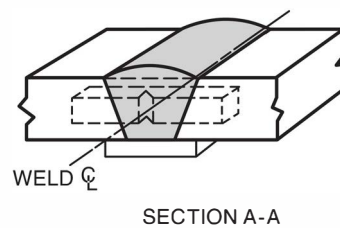
Table B.2
Filler Metal Essential Variables—FCAW-S Fill

	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
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



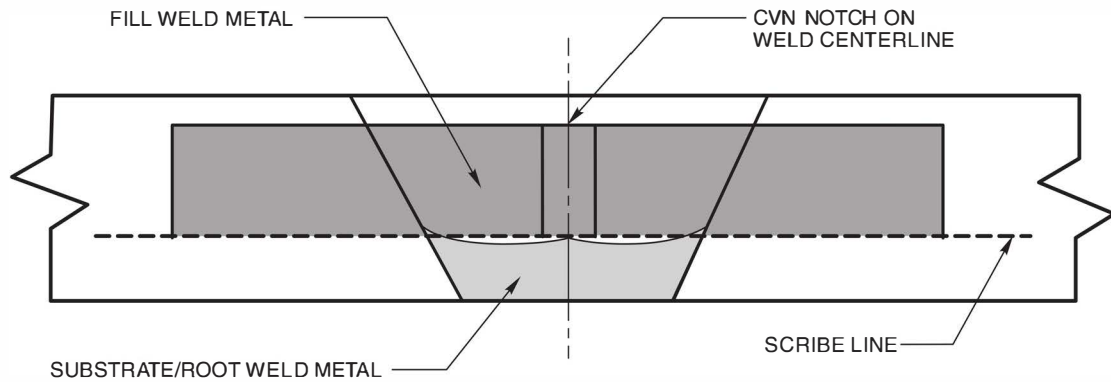
(B) ORIENTATION OF IMPACT SPECIMEN

Note: See Figures B.2 and B.4 for positioning of CVN specimen.

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

Note: CVN specimen edge to be adjacent to intermix scribe line (see Figure B.4).

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)]

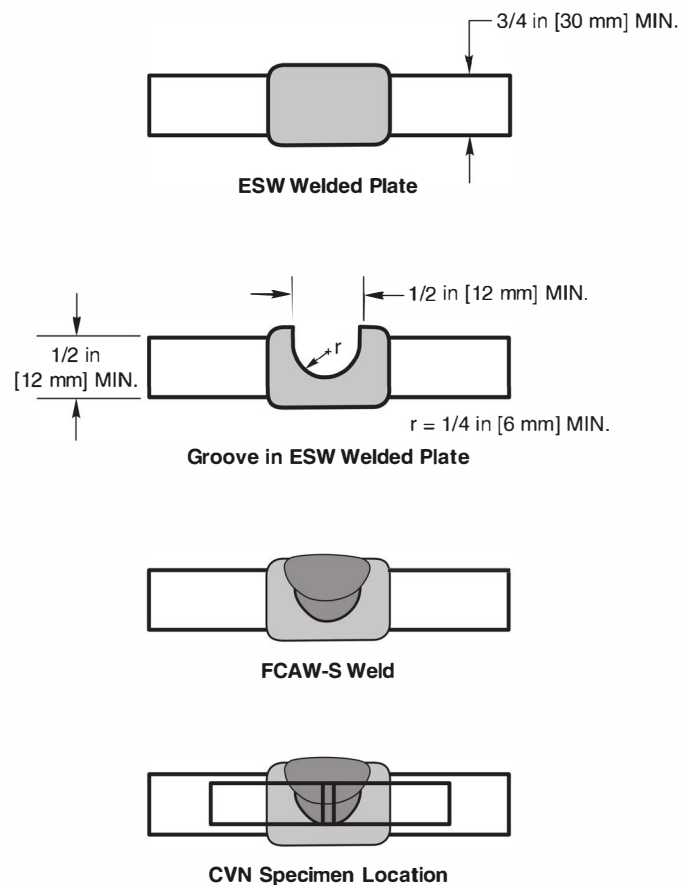


Figure B.3—ESW, FCAW Intermix Test Plate

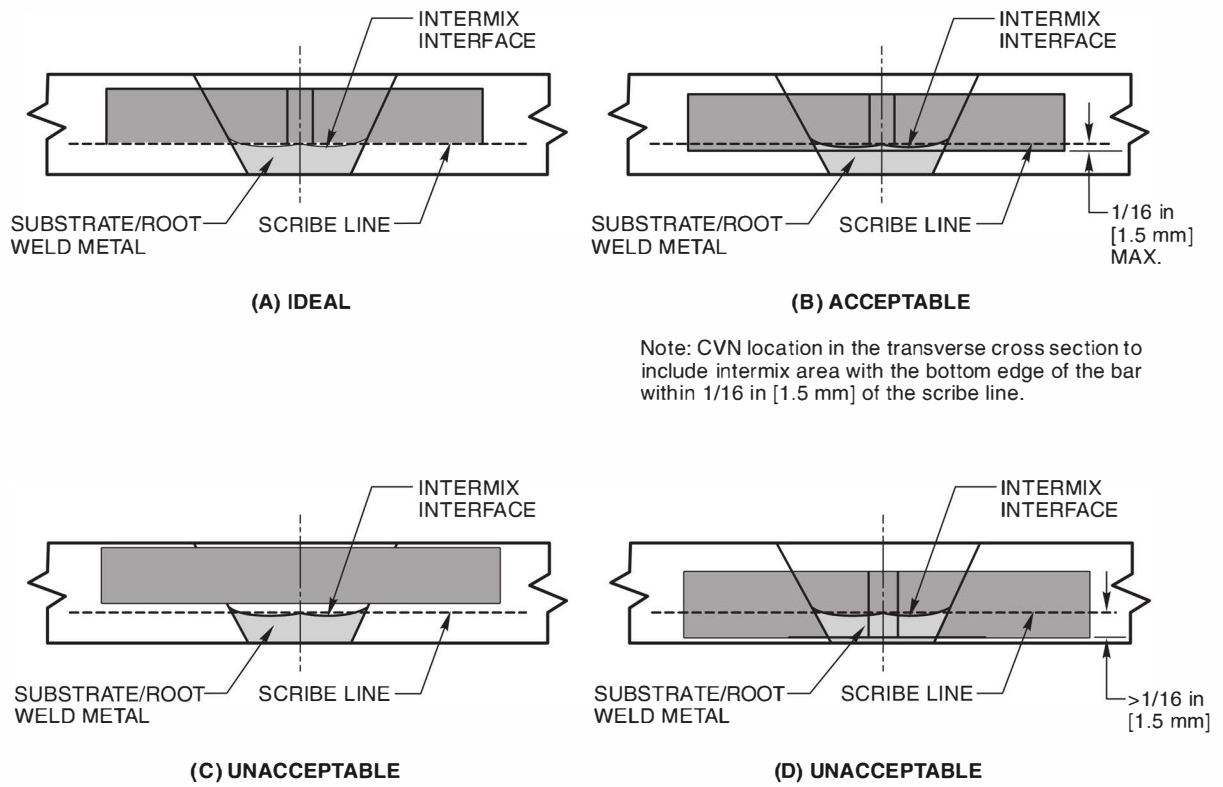


Figure B.4—Intermix CVN Test Specimen Location [see B6(3)]

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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 this standard and includes mandatory elements for use with this standard.

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, as prescribed in Clause 5.

This annex is organized as follows:

D1 Previous Qualification

D2 Test Plate Configuration

D3 Test Plate Fabrication

D4 Specimen Testing

D5 Retesting

D1. Previous Qualification

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 6.16.2, and shall conform to 6.16.1.

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 6.12.3.

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

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 Back Welding. 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 back welded 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 Back Welding. 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 back welded. The depth of backgouging shall not exceed 1/4 in [6 mm]. When the weld root is backgouged and back welded, 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:2020 6.10.1. 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:2020 6.10.3.1. 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:2020 6.3.2.

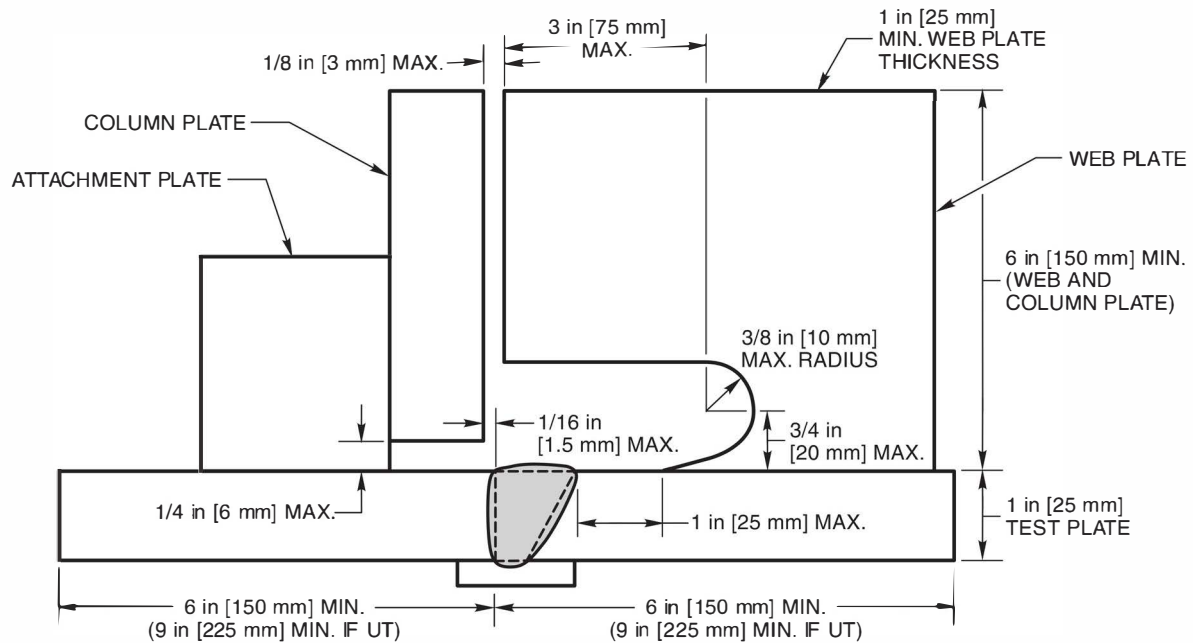
D4.2.1.3 Acceptance Criteria. Acceptance criteria for all specimens shall be in accordance with AWS D1.1/D1.1M:2020 6.10.3.3.

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:2020 6.23.3. 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:2020 8.13.2. Testing shall be performed from both the A and B face, and sides 1 and 2.

D5. Retesting

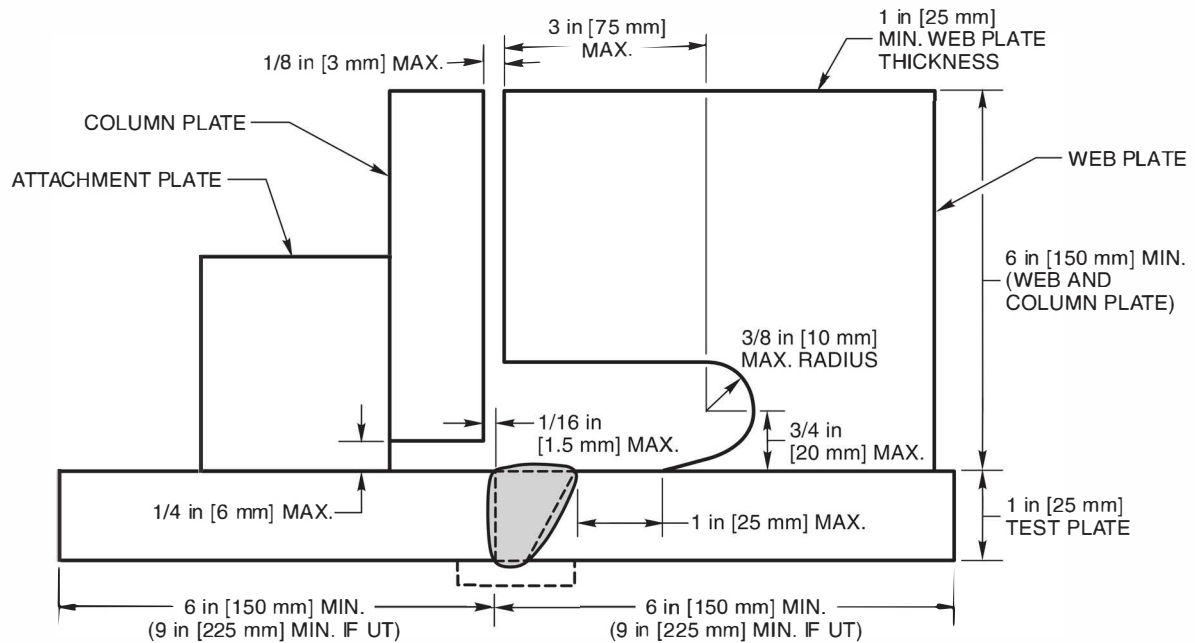
If the welder fails to pass the qualification tests prescribed in this annex, the welder may perform an additional test. If the welder fails a second test, the welder shall be not be permitted to retest until the welder has received sufficient additional training and practice.



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 ($\pm 1/16$ in [1.5 mm]) and 30° bevel ($\pm 5^\circ$).
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.

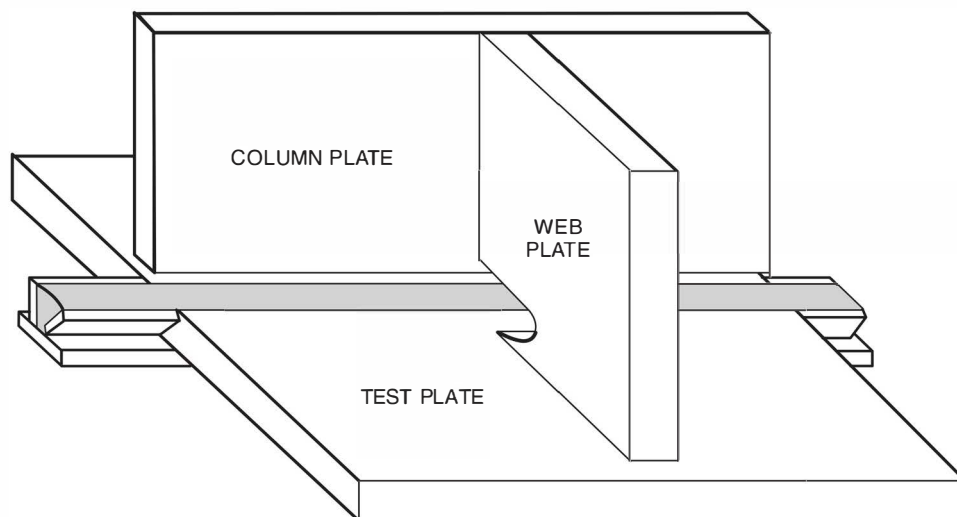
Figure D.1—Test Plate Configuration for Option A (see D2)



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.

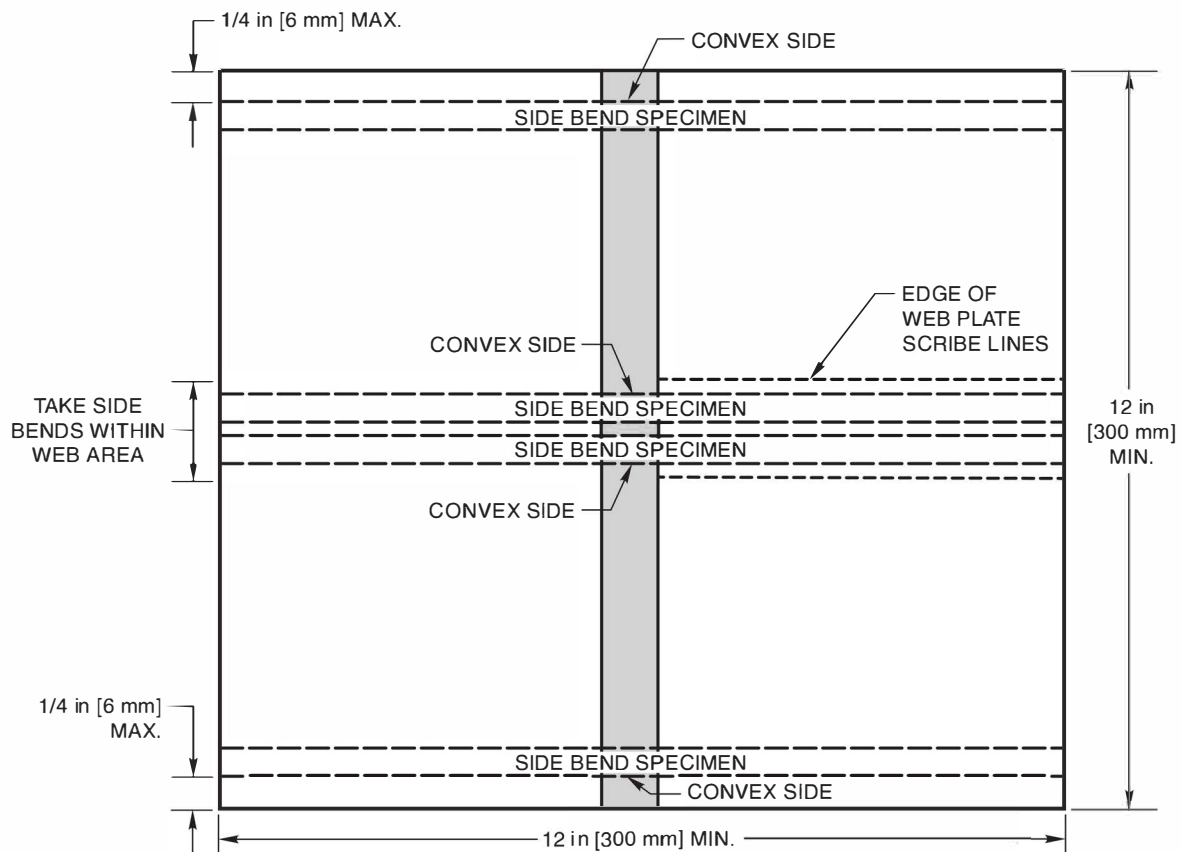
Figure D.2—Test Plate Configuration for Option B (see D2)



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:2020 6.10.3.1.
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 (see 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 this standard and includes mandatory elements for use with this standard.

The supplemental testing prescribed in this annex is intended to ensure that the diffusible hydrogen level of FCAW filler metals that are exposed for extended periods does not exceed H16, as prescribed in Clause 6.4.3.

This annex is organized as follows:

E1 Scope

E2 Test Exposure Conditions

E3 Diffusible Hydrogen Testing

E4 Exposure Limitation Criteria

E1. Scope

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:2014 16.4, except for 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 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 AWS A5.20/A5.20M 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 Qualification

This annex is part of this standard and includes mandatory elements for use with this standard.

This annex provides supplemental examination procedures using test specimen, and scoring criteria, to establish the proficiency of ultrasonic testing technicians, as prescribed in Clause 7.2.4.

This annex is organized as follows:

F1 Personnel

F2 Examination

F3 Test Specimens

F4 Candidate Scoring for Flaw Detection

F5 Period of Effectiveness

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:2020 Clause 8, Part F for Flaw Detection. Alternatively, when AWS D1.1/D1.1M:2020 Annex O is to be used, the examination shall utilize the UT techniques of Annex O, UT Examination of Welds by Alternative Techniques.

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:2020 Clause 8, Part F and for Annex Q, UT Examination of Welds by Alternative Techniques.

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:

$$D = \text{detected flaws} / \text{total flaws} \quad (1)$$

The rate of false indications, is:

$$F = \text{false indications} / \text{total indications} \quad (2)$$

The UT technician rating is:

$$R = 1/2 (1 + D - F) \quad (3)$$

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.

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Annex G (Normative)

Supplemental Magnetic Particle Testing Procedures

This annex is part of this standard and includes mandatory elements for use with this standard.

This annex provides procedures, as prescribed in 7.9, to improve the reliability of Magnetic Particle Testing (MT) to locate surface breaking flaws such as cracks and incomplete fusion that should be readily detectable with the yoke method.

This annex is organized as follows:

G1 Procedure Qualification

G2 Visual Inspection

G3 Surface Condition

G4 Method

G5 Yoke

G6 Magnetization

G7 Particles

G8 Equipment Performance Checks

G9 Yoke Placement

G10 Particle Application and Removal

G11 Interpretation and Evaluation of Indications

G12 Acceptance Criteria

G1. 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

G2. Visual Inspection

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

G3. 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.

G4. 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.

G5. 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.

G6. Magnetization

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

G7. 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.

G8. 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.

G9. Yoke Placement

G9.1 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.

G9.2 Detection of Longitudinal Discontinuities. For detection of longitudinal discontinuities, the yoke shall be placed astride and approximately perpendicular to the weld. The yoke legs shall be positioned such that the weld is approximately centered between the yoke legs. Sufficient overlap shall be used to ensure 100% coverage when moving along the weld length. Subsequent yoke positions along the weld shall be a maximum of 1/2 of the yoke leg spacing (maximum inspection distance) or 3 in [75 mm], whichever is smaller.

G9.3 Detection of Transverse Discontinuities. For detection of transverse discontinuities, 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.

G10. 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.

G11. 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.

G12. Acceptance Criteria

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

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Annex H (Normative)

Flaw Sizing by Ultrasonic Testing

This annex is part of this standard and includes mandatory elements for use with this standard.

This annex provides procedures and acceptance criteria, as prescribed in Clause 7.10.3, and Ultrasonic Testing technician qualification, to evaluate groove welds that have failed to satisfy the acceptance criteria prescribed in Clause 7.10.2.

This annex is organized as follows:

H1 Flaw Sizing

H2 Acceptance Criteria

H3 UT Technician Qualification for Flaw Sizing

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:2020 Annex Q. 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:2020 Annex Q 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.

Annex I (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

I1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

I2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

I3. General Procedure for all Requests

I3.1 Submission. All requests shall be sent to the Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

I3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

I3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

I3.4 Question(s). All requests shall be stated in the form of a question that can be answered 'yes' or 'no'. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

I3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).

I3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

I4. AWS Policy on Interpretations

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 official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

I5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the *Welding Journal*, and post it on the AWS website.

I6. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* 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.

Annex J (Informative)

Informative Reference

This annex is not part of this standard but is included for informational purposes only.

American Welding Society (AWS) standard:

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

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Commentary on Structural Welding Code— Seismic Supplement

4th 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 this standard but is included for informational purposes only.

This commentary on AWS D1.8/D1.8M:2021 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 Scope

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. Subclause 1.4.1 requires the Engineer to clearly identify on the contract documents those welds that are subject to the provisions of this code.

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 level 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 code 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 specify the requirements for design of members, connections and welded joints in the SFRS. AISC Seismic Provisions also specify 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, 1.4.1 directs the Engineer to provide the needed information to the Fabricator and Erector through the Contract Documents.

C-1.4 Responsibilities

C-1.4.1 Engineer's Responsibilities. This subclause provides a detailed list of information that the Engineer is responsible 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, 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-1.4.1 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-1.4.1 Items 5, 6, and 7. The presence of backing, weld tabs, and welds between these attachments and the members they are attached to may affect 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-1.4.1 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-6.13 and combined Commentary C-1.4.1 Items 5, 6, and 7).

C-1.4.1 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 6.15, C-6.15, and combined Commentary C-1.4.1 Items 5, 6, and 7).

C-1.4.1 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 6.16.3, 6.16.4, C-6.16.4, and combined Commentary C-1.4.1 Items 5, 6, and 7).

C-1.4.1 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 T- 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 T- or corner joints, and is not feasible for groove welds in butt joints, such as column splices (also see 6.13 and C-6.14).

C-1.4.1 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 6.11.1.1, 6.11.1.2, 6.11.1.3, 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-1.4.1 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. See Clause 3 and Commentary for Clause 3 for the definition of C-Lowest Anticipated Service Temperature (LAST).

C-1.4.1 Item 11. The 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-1.4.1 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 needed for special cases, such as those of unusually high restraint.

C-1.4.1 Item 13. A Quality Assurance Plan (QAP) is required by many Building Codes, the AISC Seismic Provisions, and AISC Prequalified Connections. The QAP is to be prepared by the Engineer, and is 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. Chapter J of the AISC Seismic Provisions specifies the minimum acceptable requirements for a QAP that apply to the construction of welded joints in the SFRS. The QAP as contained in Chapter J is recommended for adoption without unnecessary revision because consistent application of the same requirements is expected to improve reliability.

C-1.4.2.3 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 are permitted to 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:2020 7.3.2 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 can 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-1.4.2.4 Diffusible Hydrogen Content. See [6.1.2](#) and [C-6.1.2](#). This supplement requires documentation for some but not all filler metals. Exemptions are contained in [Table 6.2](#). 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-1.4.2.5 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.

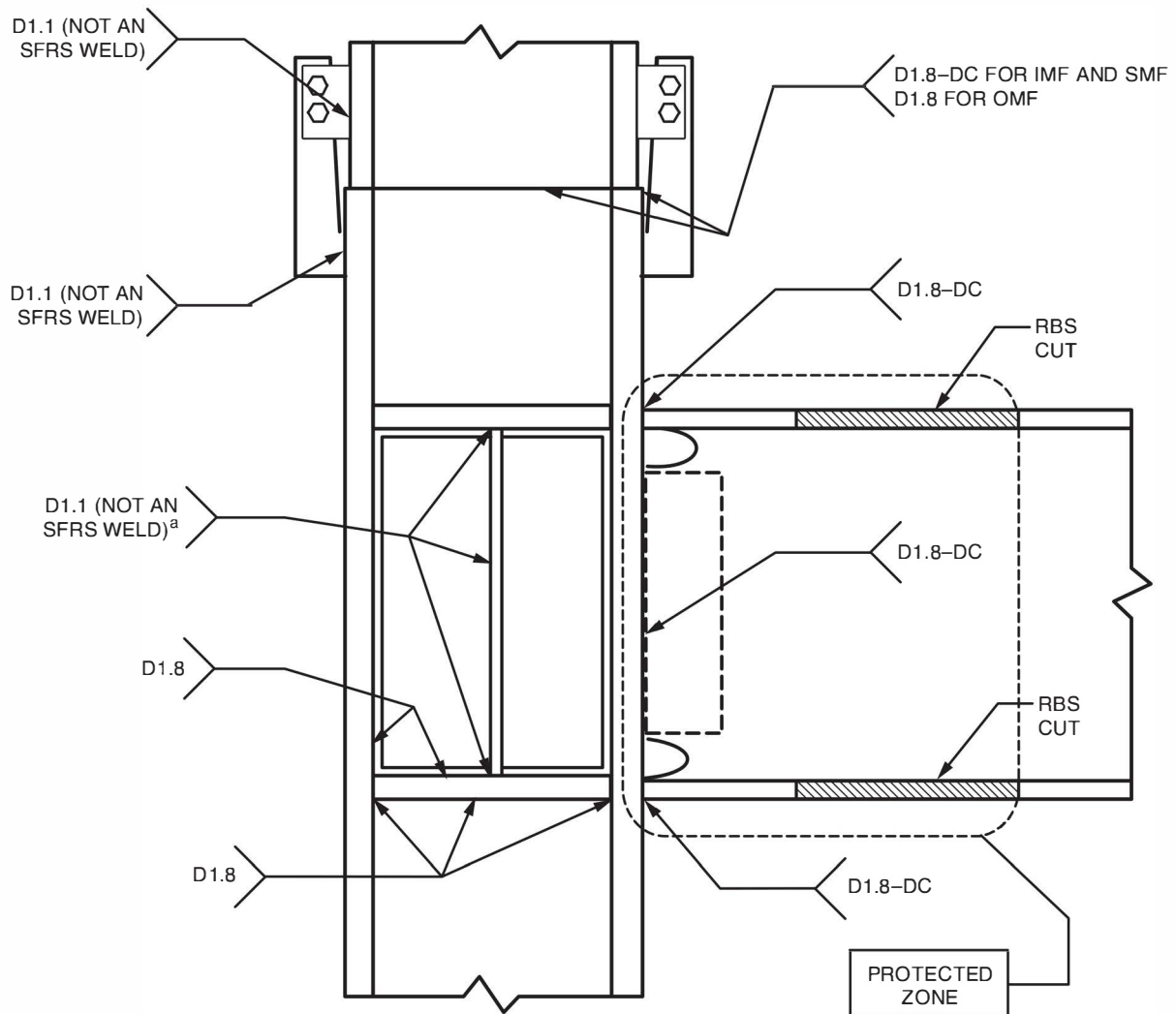
C-1.4.2.7 Supplemental Welder Qualification Testing Documentation. See Annex D and corresponding commentary.

C-1.5 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 [490 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 [490 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 Prequalified Connections)		
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 6.16.4)	—
	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

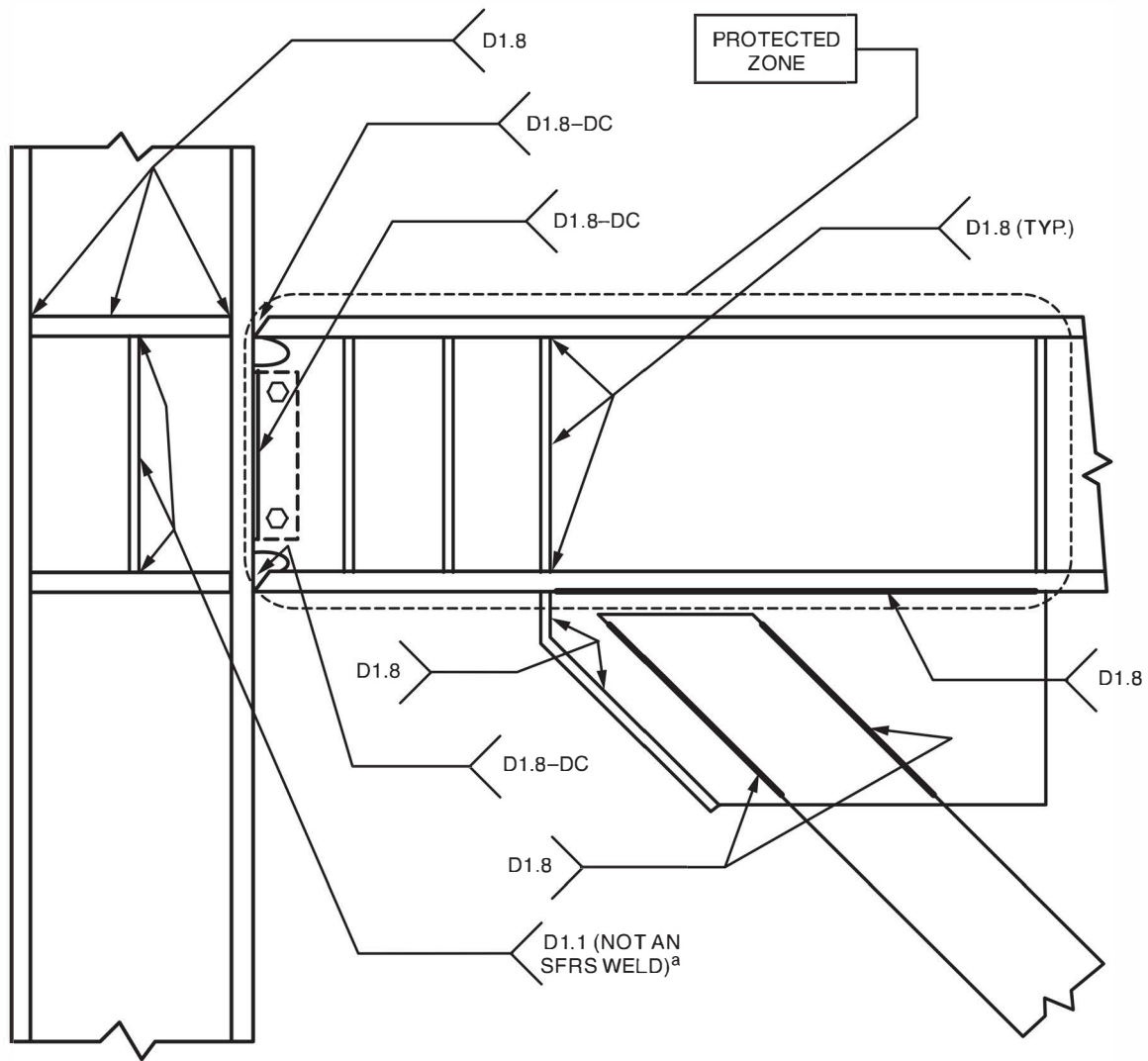


^a As shown, the member connecting to the weak axis is not an SFRS member.

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-1.4.1 Items 2, 3, and 4)

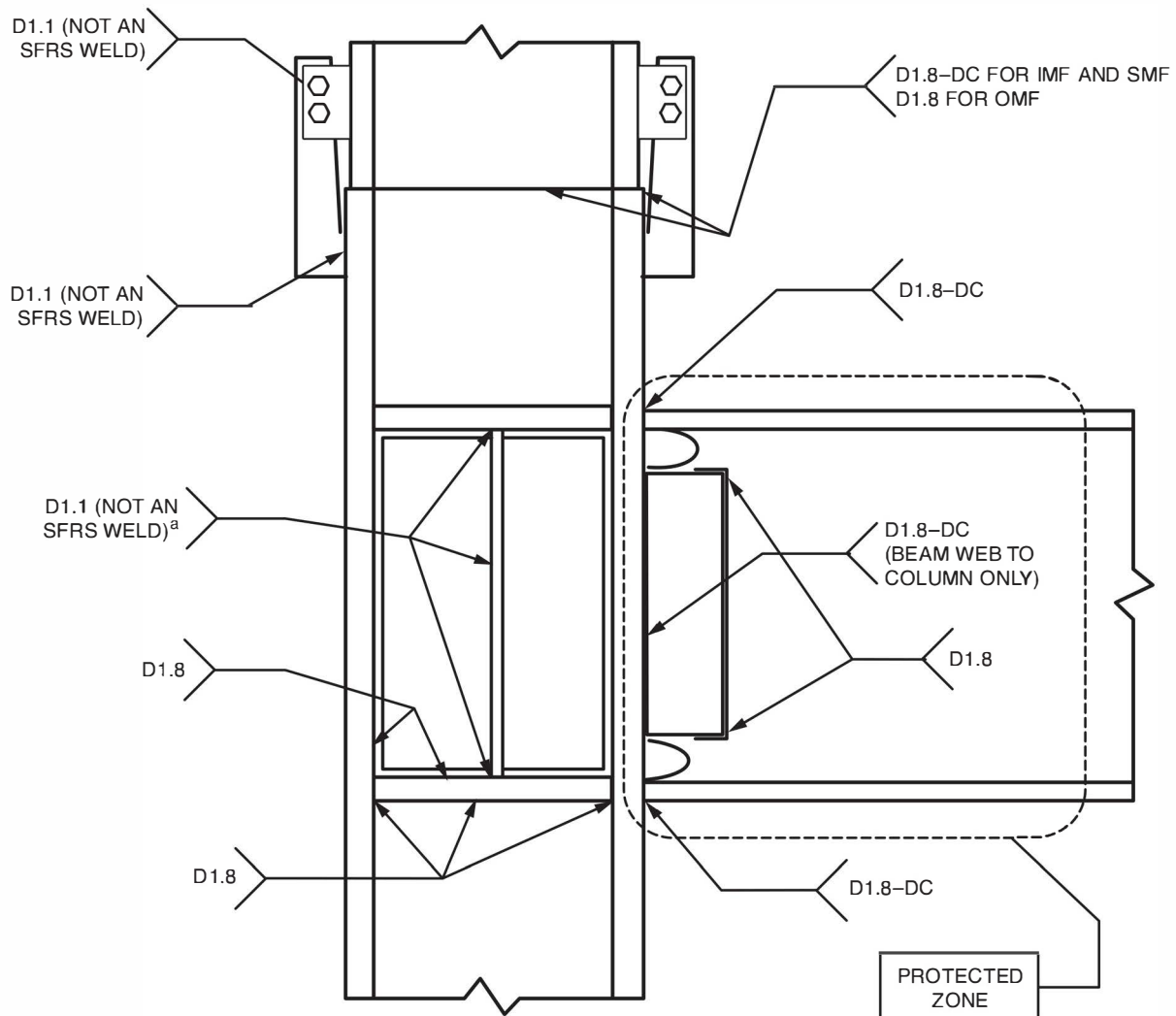


^a As shown, the member connecting to the weak axis is not an SFERS member.

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-1.4.1 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-1.4.1 Items 2, 3, and 4)**

C-3. Terms and Definitions

C-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 1.4.1(4) to identify Demand Critical welds in the Contract Documents.

AISC Seismic Provision Commentary describes “Demand Critical Welds” as follows:

“Demand Critical Weld is a weld subjected to yield level or higher stress demand and located in a joint whose failure would result in significant degradation in the strength or 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 Chapter K,
- (2) Those identified to be Demand Critical in connection qualification testing in accordance with AISC Seismic Provisions Chapter K,
- (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-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).

C-lowest anticipated service temperature (LAST)

The definition of LAST was changed in 2021 to be consistent with AISC 341. Conditions of insulation and exposure may permit a calculated increase in LAST relative to outdoor temperatures. See 1.4.1 item 10 and related commentary.

C-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, see C-6.18 for further commentary).

C-quality assurance plan (QAP)

The requirements for a QAP are specified by Chapter J of the AISC Seismic Provisions. The activities stipulated in this provision can 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-seismic force resisting system (SFRS)

The AISC Seismic Provisions provides definitions and examples of members of the seismic force resisting system.

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 A6 result in extensive cold working of the webs of rolled shapes in and near the k-area. This region is defined in Clause 3. 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-lbf at 70°F [3 J at 21°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 6.16.4). 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 1.4.1(11).

C-4.3 Joint Details for Doublers

If the doubler encroaches on the hot rolled section fillet, a space or gap is formed between the web and the doubler. The gap between the web doubler and the web is limited as follows:

- (1) For web doublers that are joined to the web with plug/slot welds, the gap is limited by the applicable code provision for those welded details.
- (2) For web doublers that are joined on the ends of the doubler with fillet welds, the gap is limited by the applicable code provisions for fit up of joints to be fillet welded.

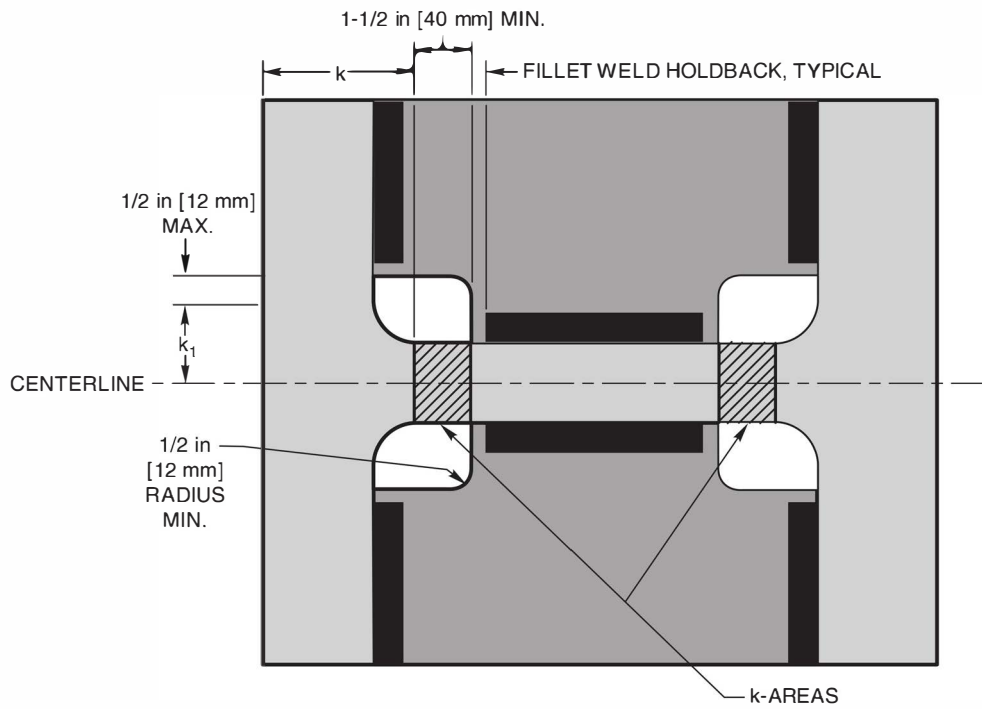


Figure C-4.1—Curved Corner Clip (see C-4.1)

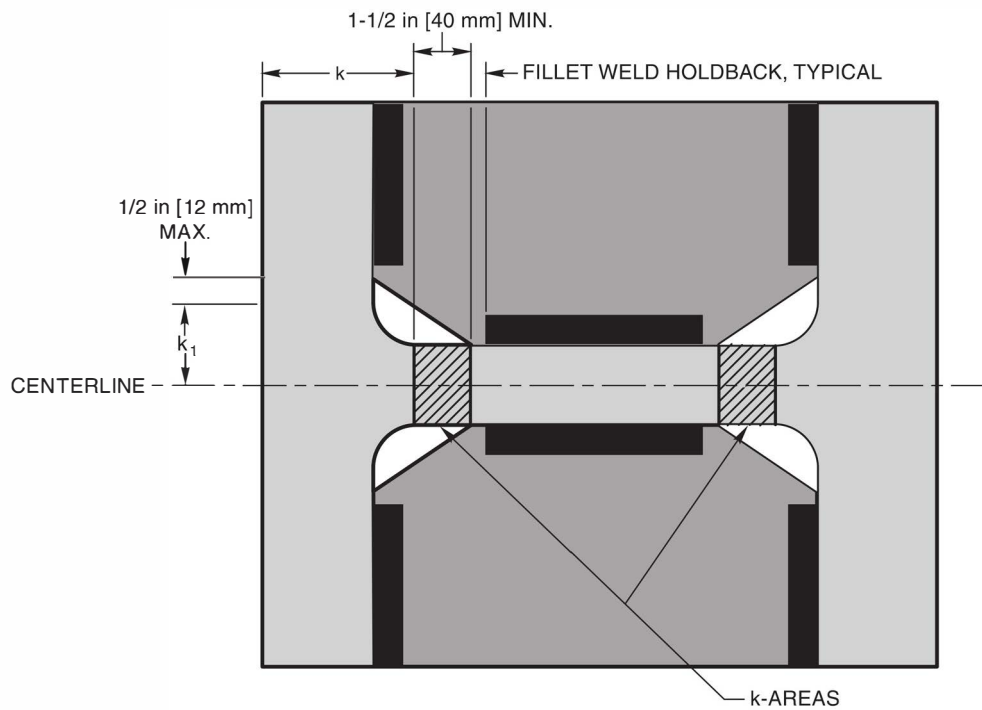


Figure C-4.2—Straight Corner Clip (see C-4.1)

C-5. Welder Qualification

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 flange 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. Welder qualification tests in AWS D1.1/D1.1M demonstrate ability to weld in various positions. This supplement does not require supplemental welder qualification tests in the various positions used in production. This qualification is not required for fillet welds or back welds of groove welds through the weld access holes.

C-5.1.2 Testing Parameters. The Supplemental Welder Qualification for Restricted Access Welding testing is required by this code to be performed using the same process (e.g., FCAW, GMAW, SAW, SMAW, etc.) that will be used in production. The testing is also to 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 by this supplement 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 Filler Metal and Weld Metal

C-6.1.1 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 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·lbf [27 J] at a temperature of 0°F [-18°C] 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·lbf [27 J], but the testing temperature was changed from 0°F [-18°C] to -20°F [-29°C].

In FEMA 353 (July 2000), the FEMA 267 recommendations for CVN notch toughness of 20 ft·lbf [27 J] at 0°F [-18°C] 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·lbf [54 J] at 70°F [21°C], 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·lbf [27 J] at -20°F [-29°C]. For the 7.3b welds, an additional CVN requirement of 40 ft·lbf [54 J] at 70°F [21°C] 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 [27 J] at 0°F [-18°C] or a lower temperature, rather than 20 ft·lbf [27 J] at -20°F [-29°C]. 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 [27 J] at -20°F [-29°C] or lower temperature, and an additional requirement of 40 ft·lbf [54 J] at 70°F [21°C] 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·lbf [27 J] in the AWS classification test, and 40 ft·lbf [54 J] at 70°F [21°C] 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 [-18°C] for all welds as was recommended in FEMA 267 and FEMA 353, not the -20°F [-29°C] 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-1.4.1).

The 2016 edition of this supplement added provisions for the use of E90 [E62] filler metals to weld 70 ksi [490 MPa] yield steel that was accepted for use in seismically loaded structures in the AISC Seismic Provisions. In response to the higher stresses potentially in these welds the classification toughness requirements were set to 25 ft-lbf [34 J] at -20°F [-29°C] and the service temperature tests were set at the lowest anticipated temperature without a 20°F [11°C] temperature shift.

C-6.1.2 Diffusible Hydrogen Level. All welding electrodes for processes approved by this code (see 6.5) are expected to meet the diffusible hydrogen requirements for H16. This provision also applies to each SAW electrode/flux combination to be used on the project. Carbon steel FCAW electrodes need to meet the further testing restrictions described in AWS A5.20/A5.20M Clause 16. Low alloy FCAW electrodes tested to the diffusible hydrogen requirements in AWS A5.29/A5.29M Clause 15, that meet the requirements of H16 or less are acceptable for use in Demand Critical welds. 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 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 by this supplement (see 1.4.2.4). SMAW electrodes may be accepted based upon moisture content.

C-6.1.4 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. This supplement requires testing of intermixed weld metal 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.

Several intermix tests were performed before the issuance of this code in 2005. These included both tests performed in accordance with FEMA 353, as well as research performed in conjunction with various SAC investigations. Prior to 2021, this code permitted the use of intermix tests other than those performed in accordance with Annex B. This option to use intermix tests other than those in accordance with Annex B was deleted to standardize testing methods.

C-6.2 Heat Input Envelope. Clause 6.2.1 of this code requires testing of weld metal produced by selected filler metals at both the maximum and minimum permissible limits of heat input.

Testing of heat-affected zone (HAZ) notch toughness is not required by this code. However, this should not be interpreted to mean that HAZ notch toughness is not an important consideration in the design of seismically loaded structures. In particular, the effect of heat input on HAZ notch toughness should be considered when the heat input is greater than about 80 kJ/in [3.1 kJ/mm].

The effect of welding heat input on HAZ notch toughness has been studied by Cane and Dolby (1974), Johnson and Ramirez (2000) and others (see References 1 and 2). The studies generally show that the ductile to brittle transition temperature tends to increase with increasing heat input. Johnson concluded that “welding heat inputs ranging from 30 kJ/in to 70 kJ/in [1.2 kJ/mm to 2.8 kJ/mm] should not result in a substantial degradation of HAZ notch toughness.”

In addition to welding process and parameters, the composition of the parent material directly affects the hardness, microstructure and toughness of the HAZ (see Reference 3). HSLA steels may use small additions of Nb, V, Ti, B, N and other elements to develop strength and toughness in the parent metal as well as in the HAZ. Nonmetallic inclusions in the steel, such as sulphides and other inclusions, adversely affect HAZ notch toughness (see References 4 and 5).

With the SMAW, FCAW, and GMAW processes the welding heat input rarely exceeds 80 kJ/in [3.1 kJ/mm]. The same applies to SAW with a single wire. With multiple wire SAW a heat input of greater than 80 kJ/in [3.1 kJ/mm] is not uncommon and with ESW the heat input is typically greater than 80 kJ/in [3.1 kJ/mm] (see References 6 and 7). It is with these higher heat input processes that consideration of HAZ notch toughness may be necessary.

When heat inputs higher than 80 kJ/in [3.1 kJ/mm] are to be used, the engineer may want to specify additional testing to prove that the steel being welded will provide acceptable notch toughness in the HAZ.

C-6.2.1 WPS Heat Input Envelope Testing Properties. The purpose of WPS Heat Input Envelope Testing prescribed in Annex A is to demonstrate that the minimum required strength, ductility, and CVN toughness will be achieved in the weld metal 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 [E49] and E80 [E55] 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 supplement does not require that WPSs be qualified by test. However, to ensure that the required mechanical properties are achieved in production, this supplement 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 still applies. 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 [21°C] test temperature was established by the same research. This value is typically appropriate for enclosed buildings. When specified by the Engineer in accordance with 1.4.1(10), alternate test temperatures are required.

CVN testing of weld metal in accordance with Annex A, but performed at a temperature lower than the required test temperature, automatically meets the CVN requirements of Table 6.3 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 6.3. SMAW performed with either E7018 [E4918] or E8018 [E5518] electrodes, or GMAW performed with solid electrodes, routinely deposit welds with these mechanical properties and therefore, it is not necessary to perform the tests required by Annex A for these processes/filler metals.

Subclause 6.8.1 of this code requires that WPSs be operated within the range of heat inputs, a heat input envelope, which have been tested. Previous editions of this code have included use of the supplemental designator “D” for carbon steel FCAW electrodes tested by the manufacturer as described in Clause 17 of AWS 5.20/A5.20M:2005. The testing used to classify a filler metal with “D” was similar, but not identical to, the testing defined in Annex A. It was accepted to use such testing as an alternative to Annex A testing. The heat input envelope indicated by the designator “D” was 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 to 80 kJ/in [1.2 kJ/mm to 3.1 kJ/mm] heat input range (unless tested at alternate limits), regardless of electrode diameter. AWS A5.20/A5.20M was revised in 2021 and eliminated the “D” designator. Therefore, the “D” designator has been removed from D1.8/D1.8M. For carbon steel FCAW electrodes over 3/32 in [2.4 mm] in diameter with the “D” designator, the heat input range should be limited to 40 kJ/in [1.6 kJ/mm] to 80 kJ/in [3.1 kJ/mm] until such time as testing using Annex A provides another heat input range.

C-6.2.2 Lowest Anticipated Service Temperature Applications. The use of a testing temperature not more than 20°F [11°C] higher than the LAST is to adjust for the effect of loading rate in 70 ksi [490 MPa] and 80 ksi [550 MPa] filler metals. For 90 ksi [620 MPa] filler metals, the effect of loading rate is less, therefore no temperature shift is permitted. The Engineer needs to specify the LAST when this is less than 50°F [10°C]. This provision applies only to Demand Critical welds [see 1.4.1(10), Clause 3]. For example, if LAST is 5°F [–15°C], then the testing temperature should be no higher than 25°F [–5°C] for welds using 70 ksi [490 MPa] or 80 ksi [550 MPa] filler metals or 5°F [–15°C] for welds using 90 ksi [620 MPa] filler metals.

C-6.3.3 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 pro-

vides 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-6.3.4 Exemptions. SMAW performed with either E7018 [E4918] or E8018 [E5518] 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 6.3.2 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 exposure time limit 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 is 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 Welding Processes

C-6.5.1 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.

C-6.5.2 Other Processes for Demand Critical Welds. Specific WPS parameters are not required to be qualified by connection qualification tests. Unless approved by the Engineer, processes other than those listed in 6.5.1 (but not the specific WPS parameters) are required by this code 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 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 6.5.1. 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-6.6 Welding Procedure Specifications (WPSs)

WPSs for Demand Critical welds are required by this code to be based on the heat inputs used for the testing described in Annex A. The Contractor is required by this supplement to record the filler metal manufacturer and trade name of the product used in the WPS because the heat input envelope could be different for each manufacturer and filler metal manufacturer and type. The parameters chosen for the WPS are required by this code to 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 are required by this code to result in a calculated heat input between the high and low heat inputs tested. The AWS D1.1/D1.1M heat input calculation is used to calculate heat input and establish the WPS parameters, e.g., Heat Input (kJ/in) = $(60 \times \text{volts} \times \text{amps}) / (1000 \times \text{travel speed})$ (in inches per minute) [Heat Input (kJ/mm) = $60 \times \text{volts} \times \text{amps} / 1000 \times \text{travel speed}$ (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 needs to show limits that will ensure that the welder will not exceed the maximum deposition rate for which he/she is qualified.

C-6.6.3.1 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 (see References 8 and 9).

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-6.6.3.2 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] (see References 8 and 9).

C-6.7 Maximum Interpass Temperature

C-6.7.1 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-6.2.1 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 [288°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-6.7.2 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 is 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-6.9 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-6.10 Welder Identification

A welder identification system is required by this supplement 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.

If used, welder identification stamps are required to be low-stress type 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-6.11 Weld Access Holes

C-6.11.1.1 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 1.4.1(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 AISC 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-6.11.1.2 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 (see Reference 10).

C-6.11.1.3 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 are to be fully defined, including applicable tolerances.

C-6.11.2 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 needed, 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 6.11.2.1 is not significant, and need not be controlled.

C-6.12 Tack Welding Requirements

C-6.12.1 Preheat. Tack welding is required by this supplement 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-6.12.2 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 are required by this supplement to be placed such that they will subsequently be covered by a weld.

C-6.12.3 Tack Welds to Steel Backing in the Protected Zone. Tack welds for beam flange to column connections are required by this supplement to 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 by this supplement. The tack welds holding weld tabs are required by this supplement to be removed in accordance with 6.16.3.

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 in accordance with Clause 6.1.4. Tack welds in joints need to be of a size and configuration so as to not interfere with subsequent weld passes (see AWS D1.1/D1.1M:2020 7.17). 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-6.12.4 Removal of Improperly Placed Tack Welds. If tack welds are inadvertently made in the Protected Zone, the tack welds are required by this supplement to be completely removed and the base metal ground smooth and flush.

C-6.13 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 6.15 and Reference 11).

C-6.14 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-6.15 Fillet Welds at Left-in-Place Steel Backing

C-6.15.1 Minimum Fillet Weld Size. In situations where backing is permitted to remain, it is 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 1.4.1(6) (see Figure C-6.2).

C-6.15.2 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 6.18.4 (see Figure C-6.2).

C-6.16 Weld Tabs

C-6.16.1 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 at the clipped corner. Similar conditions exist in the corners of continuity plates adjacent to the k-area of columns.

C-6.16.2 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-6.16.4 Weld Tabs for Continuity Plates. Detailing of the corners of continuity plates needs to account for 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 6.16.1 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 6.16.1.

C-6.17 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 by this supplement because welds placed into the resultant corner are likely to contain defects. End dams prohibit molten weld metal and slag from dripping from the end of the weld which can injure workers below and cause fires. 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 by this supplement 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-6.18 Protected Zone

C-6.18.1 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" (see Reference 10).

C-6.18.2 Erection Aids. There may be some instances where erection aids need 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 need to 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 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-6.18.4 Correction of Errors. When fillet welds are placed between the backing and the column in T-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-6.18.5.1 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

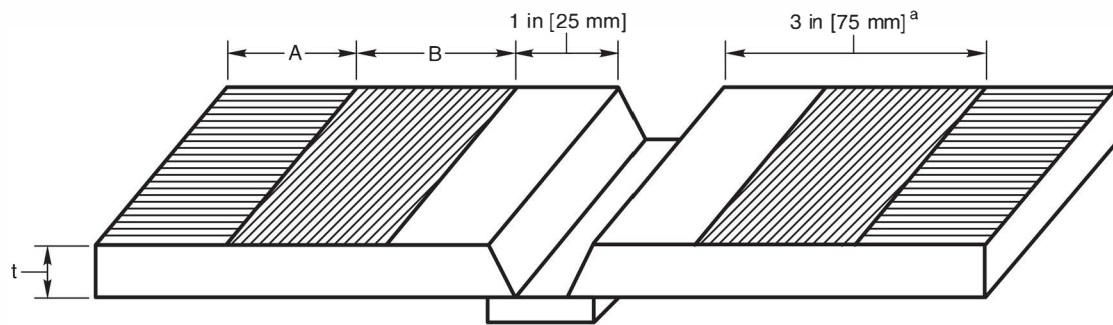
stress, yet the member axis is clear to anyone working with the steel. When repairs are made by grinding, the slope of the repair, in the direction of the axis of the member, is required by this supplement to be less steep (e.g., 1:5) as compared to the situation where the slope is perpendicular to the member axis (1:2.5).

C-6.18.5.2 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 by this supplement. MT is utilized to ensure there are no surface breaking cracks in the completed repair weld. The provisions for gradual transition of 6.18.5.1 still apply. The slope control applies to either a depression (as is always the case in 6.18.5.1, 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.

C-6.18.6 Repair of Mislocated Holes. One method of restoring unacceptable holes is to fill one-half the depth or less with steel backing of same material specification as the base metal. Gouge or grind an elongated boat shaped cavity, then fill cavity by welding with stringer beads. After the first side is welded, gouge another elongated boat shaped cavity, completely removing the temporary backing on the second side, and complete welding using the stringer bead technique.

References for Clause C-6

1. Cane, M. W. F., and R. E. Dolby, 1974, Metallurgical Factors Controlling the HAZ Fracture Toughness of Submerged-Arc Welded C-Mn Steels, *Welding Research International*, 4 (3).
2. Johnson, M. Q., and J. E. Ramirez, *Preliminary Evaluation of Heat Affected Zone Toughness in Structural Shapes used in the Construction of Seismic Moment Frames*. Redwood, CA: Applied Technical Council, October 17, 2000.
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5. Dolby, R. E., “HAZ Toughness of Structural and Pressure Vessel Steels—Improvement and Prediction,” *Welding Journal*, August 1979.
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7. Dolby, R. E., The HAZ Toughness of Electroslag Welds in C-Mn Steels, TWI M/87175.
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9. Johnson, M. Q., *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*, Report No. SAC/BD-00/12, September 24, 2000.
10. Ricles, J. M. C., Mao, L. Lu, and J. Fisher., *Development and Improvement of Improved Details for Ductile Welded Unreinforced Flange Connections*, Report No. SAC/BD 00/24, August 2000.
11. Chi, W. M., G. Deierlein, A. Ingraffea, *Finite Element Fracture Mechanics Investigation of Welded Beam-Column Connections*, Report No. SAC/BD-97/05, December 15, 1997.



^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-6.7.1)

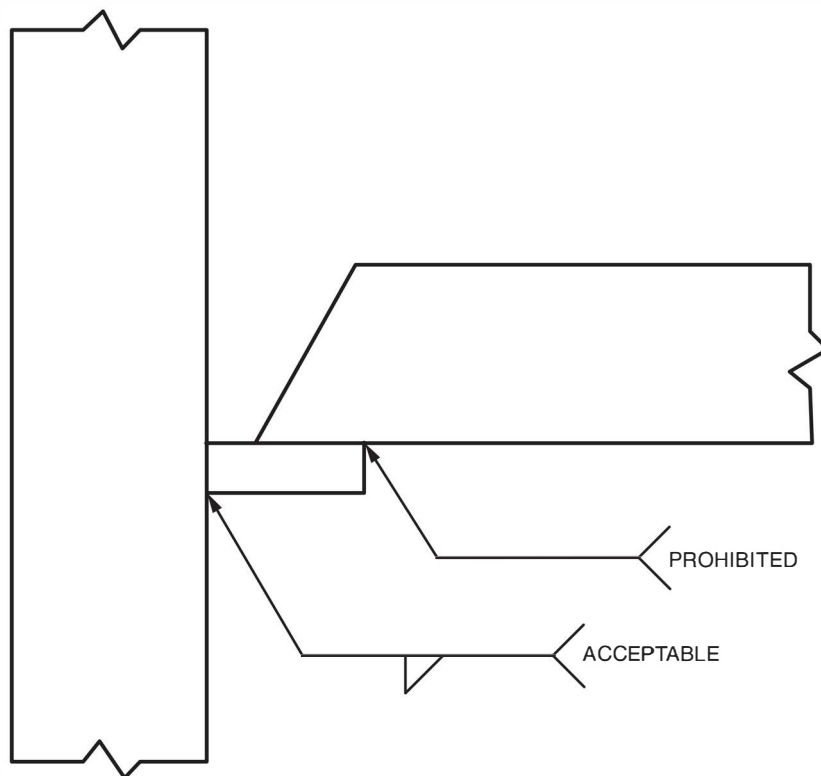
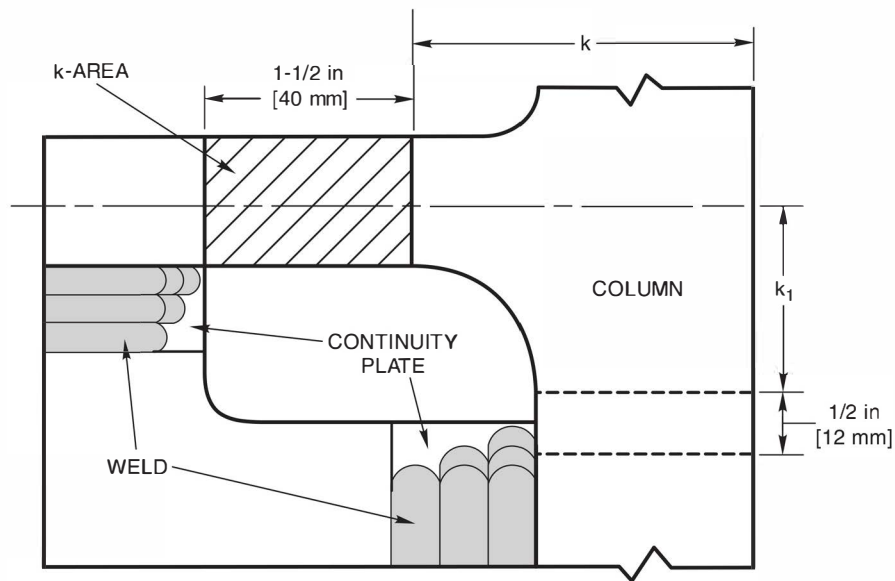


Figure C-6.2—Beam Flange to Column—Fillet Welds at Left-in-Place Steel Backing (see C-6.15.1, C-6.15.2, C-6.18.4)

**(A) ACCEPTABLE**

Note: Curved cope shown, straight cope is acceptable.

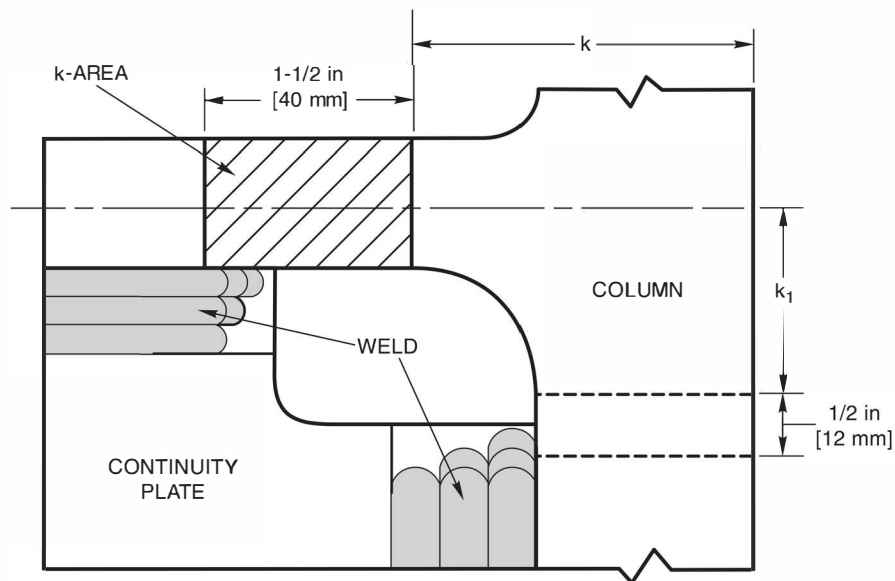
**(B) NOT RECOMMENDED**

Figure C-6.3—Continuity Plate Copes without Weld Tabs (see 6.16.4 and C-6.16.4)

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 to provide the QAP as part of the Contract Documents (see C-1.4.1 Item 13). The AISC Seismic Provisions, Chapter J includes 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:2020 Clause 8, Part F procedures. Annex F of this code 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:2020 Clause 8, 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 E329, *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 doublers, 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 doublers 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 [38 mm], loaded in tension in the through thickness direction (due to weld shrinkage strains) in T- and corner joints, where the connected material is greater than 3/4 in [20 mm] and contains CJP groove welds. The IBC contains similar provisions. Inspection of thinner base metal loaded in the through thickness direction is typically not justified. AWS D1.1/D1.1M:2020 Table 8.3 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 to be accepted or rejected based upon AWS D1.1/D1.1M:2020 Table 8.3.

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 6.11.2). 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 [38 mm] for rolled shapes, or when the web thickness exceeds 1-1/2 in [38 mm] for built-up shapes.

C-7.10 Ultrasonic Testing

C-7.10.1 Technique. This code requires that documented and qualified UT procedures be developed for ultrasonic testing for Demand Critical (DC) Welds which are specific to the DC weld joints that are to be tested. AWS D1.1 Annex O, Clause O3, provides the information to be included in a joint-specific written procedure, even if using AWS D1.1 standard procedures and Table 8.2. The requirement for a qualified written procedure anticipates extra techniques or variations of techniques that may be necessary to provide full coverage of the specific joint or to provide evidence that the AWS D1.1 standard UT procedures provide full coverage of the tested joint.

The reference to AWS D1.1 Annex O, Figure O3 (which references Clause O5) is a way to show that full coverage of the weld volume is attained. Clause O5 requires that the side drilled holes be placed "... in locations where it is difficult to direct sound beams, thereby ensuring detection of discontinuities in all areas of interest." The ASNT Level III Technician can decide the exact placement of the side drilled hole(s) in the mockup and how many mockups are necessary to prove the UT procedure. One common situation is a T-joint with steel backing. In this situation, the procedure may need to show that full coverage is obtained in the root from a third leg Side A scan or to interpret reflected sound beams coming from geometric reflectors. Research (Ref 1) has shown that ultrasonic technicians can have difficulty evaluating weld flaws which occur in the vicinity of backing. Guidance for ultrasonic testing on groove welds with steel backing is also provided in AWS D1.1:2020 8.25.12.

C-7.10.2 Acceptance Criteria—Flaw Detection. The use of alternative techniques other than those prescribed by AWS D1.1/D1.1M:2020 Clause 8 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:2020 7.25 as well as the general requirements of this code. 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 the following:

- (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:2020 C-8.25.12 for discussion of these issues).

Reference for Clause C-7

1. "Ultrasonic Testing Procedures, Technician Skills, and Qualifications", R. E. Shaw, Journal of Materials in Civil Engineering, February 2002.

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C-Annex A

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

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-A1. 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 range. 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, provided the higher limits have been successfully tested.

C-A2. 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 temperature 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-A4.2.

C-A4. 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 A4.3). 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-A4.2 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.

For conventional power sources that do not use waveform-controlled welding, heat input is calculated by the following formula:

$$H = 60 \frac{V}{I/S} \quad (4)$$

where:

H = heat input,
 V = 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].

For welding procedures using two or more electrodes in one weld pool, heat input is the sum of the heat inputs calculated from the voltage and current from each power source if more than one power source is used. If a single power source is used, the heat input is calculated from the voltage and current from that power source and travel speed.

For procedures using multiple wires in separate weld pools, the heat input for the low heat input test is the lower of the heat inputs, and the heat input for the high heat input test is the higher of the heat inputs. For welding procedures using power sources with waveform-controlled welding see AWS D1.1/D1.1M:2020 Clause 6.8 and Reference 1.

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 AWS 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-A6. Acceptance Criteria

C-A6.1 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 E90 [E62] filler metal is required. All tensile testing is done at room temperature, regardless of LAST, if specified.

C-A6.1 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 [11°C] for welds using 70 ksi [490 MPa] or 80 ksi [550 MPa] filler metals and LAST for welds using 90 ksi [620 MPa] filler metals. For other applications, testing is done at 70°F [21°C] for welds using 70 ksi [490 MPa] or 80 ksi [550 MPa] filler metals and 50°F [10°C] for welds using 90 ksi [620 MPa] filler metals (see 6.2.2).

Reference for C-Annex A

1. Melfi T., "New Code Requirements for Calculating Heat Input," *Welding Journal*, June 2010.

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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 6.1.4. 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-6.1.4).

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-B3.2 Intermix with ESW

Provisions were added to permit welding with FCAW-S over ESW welds. The concept of performing CVN tests of specimens machined from intermixed weld metal remains the same as it is for the other welding processes. Welding part of a butt joint is not possible with ESW, therefore the test specimen is made by welding the full joint with ESW, removing ESW metal and rewelding with FCAW-S to provide intermixed weld metal to test.

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 used, 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] or −20°F [−29°C]. When testing is being performed for Demand Critical welds, one set of five specimens is prepared for testing at 0°F [−18°C] or −20°F [−29°C], and another set of five is prepared for testing at 70°F [21°C] or 50°F [10°C]. A single set of five specimens may be used to satisfy both the lower temperature requirement for all welds governed by this code, as well as the higher temperature requirement for Demand Critical welds, providing the testing performed at the lower temperature demonstrates an absorbed energy level no less than 40 ft·lbf [54 J]. It is possible, however, that a weld deposit may be able to achieve the required energy at the required test temperatures but not be able to achieve the energy required for the higher test temperature when tested at the lower test temperature.

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 6.2.2.

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 [11°C] except for E90 [E62] filler metals where the test temperature is equal to the LAST. For other applications, testing is done at 70°F [21°C] (see 6.2.2).

C-Annex D

Supplemental Welder Qualification for Restricted Access Welding

C-D1. Previous Qualification

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 (see 5.2), 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 Backgouging and Back Welding. 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 back welding 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 Back Welding. The Supplemental Welder Qualification for Restricted Access Welding—Option B test does not require that the weld root be backgouged and back welded 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 back welding 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 is 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:2020 6.23.3. 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. Scope

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 Qualification

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-G9. Yoke Placement

C-G9.2 Detection of Longitudinal Discontinuities. The effective area of inspection is between the yoke legs, with a longitudinal area of approximately 1/2 of the yoke leg spacing. For example, with 6 inches between the yoke legs, movement in 3 in [75 mm] intervals, measured center to center, should ensure adequate overlap (see Figure C-G.1). The periodic use of a magnetic field indicator (“pie gage”) is encouraged to verify the orientations of detectable discontinuities with a given yoke position.

Yoke orientation has little effect on MT sensitivity or coverage within a range that would be considered nominally perpendicular. Therefore, yoke orientation does not have to be measured and there are no specified tolerances for perpendicularity. Any nominally perpendicular orientation is acceptable.

C-G9.3 Detection of Transverse Discontinuities. 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]. The periodic use of a magnetic field indicator (“pie gage”) is encouraged to verify the orientations of detectable discontinuities with a given yoke position.

C-G11. 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.

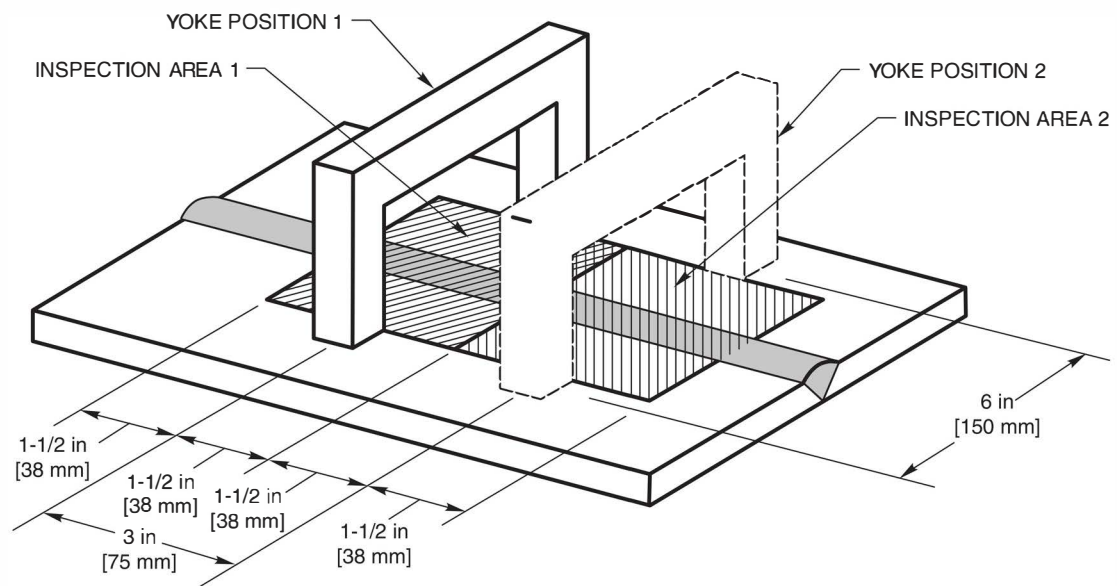


Figure C-G.1—An Example of Effective Areas of Inspection Between Yoke Legs (See C-G10.2)

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] (see References 1 and 2).

References for C-Annex H

1. FEMA 355B, *State of the Art Report on Welding and Inspection*, Subclause 7.4, Federal Emergency Management Agency, 2000.
2. Mohr, W., *Weld Acceptance Criteria for Seismically-Loaded Welded Connections*, Report No. SAC/BD 99/24, March 27, 2000.

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List of AWS Documents on Structural Welding

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

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