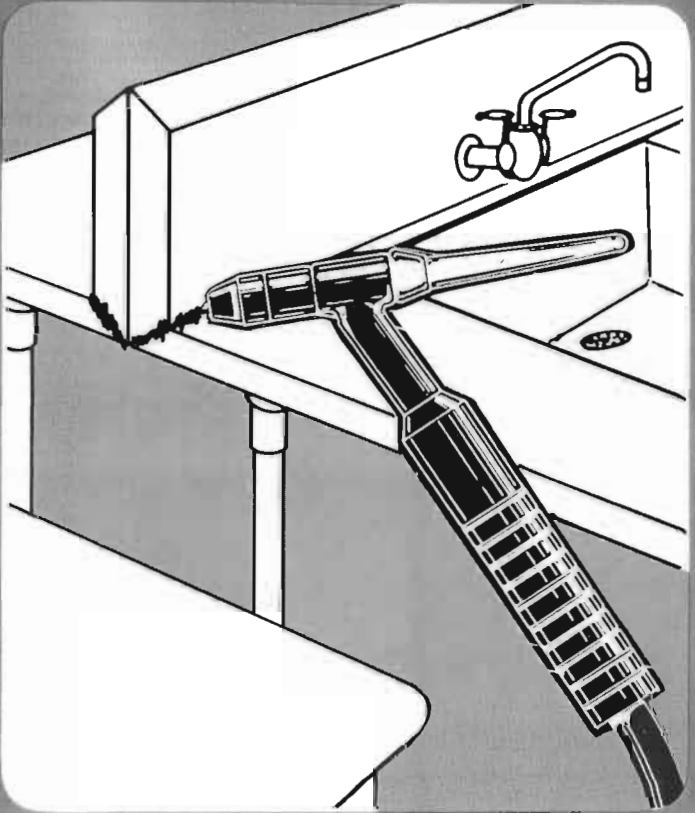
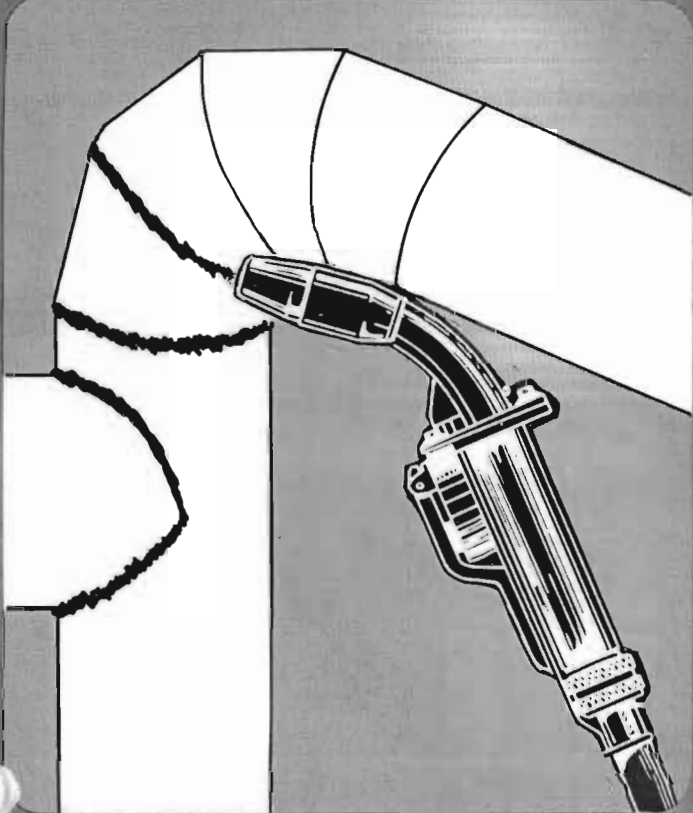
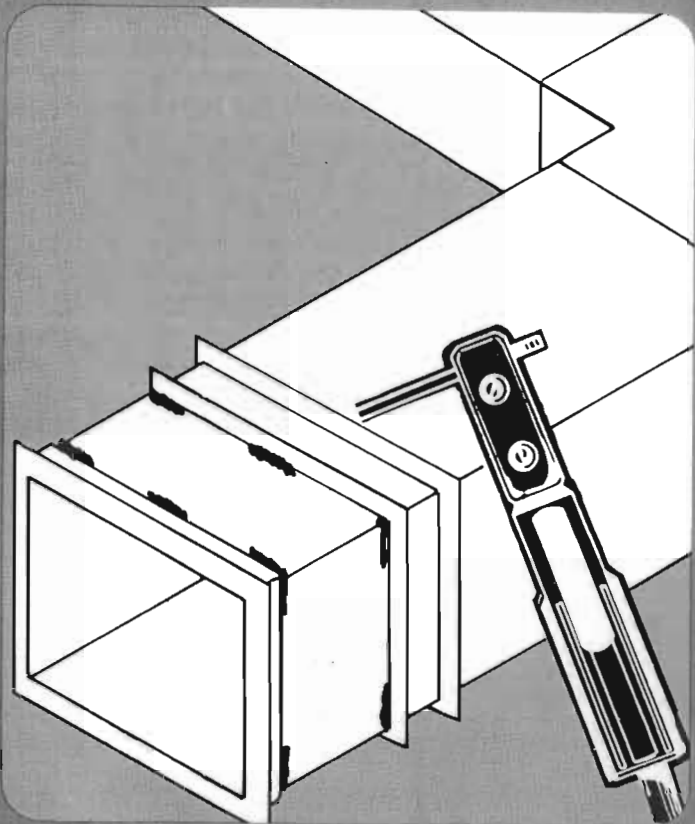


Sheet Metal Welding Code



Keywords — Sheet metal, arc welding,
braze welding, joint designs,
qualification, workmanship,
inspection, base metals,
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Sheet Metal Welding Code

Superseding D9.1-84

Prepared by
AWS Committee on Welding, Brazing,
and Soldering of Sheet Metal

Under the Direction of
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This Code covers the arc and braze welding requirements for nonstructural sheet metal fabrications using the commonly welded metals available in sheet form. Requirements and limitations governing procedure and performance qualification are presented, and workmanship and inspection standards are supplied. The nonmandatory appendices supply useful information on materials and processes.



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Sheet Metal Welding Code

1. Scope, Purpose and Applications

1.1 Scope. This Code provides qualification, workmanship, and inspection requirements for both arc welding (Part A) and braze welding (Part B) as they apply to the fabrication, manufacture, and erection of nonstructural sheet metal components and systems.

1.2 Purpose. It was written to standardize acceptance criteria for sheet metal fabrication in nonstructural applications.

1.3 Applications. This Code has general applications in the following industrial areas:

- (1) Heating, ventilating, and air conditioning systems
- (2) Food processing equipment
- (3) Architectural sheet metal and similar applications
- (4) Other nonstructural sheet metal applications

It covers the thickness range for sheet metal up to as thick as 3 gauge, or 0.239 in. (6.07 mm). See Appendix C. It applies to the attachment and joining of any member, regardless of thickness, whose sole purpose is stiffening, supporting, or reinforcing the sheet metal. It also applies to the attachment of accessories or components of the system.

Where vacuum or pressure exceeds 120 in. of water (30 kPa) or where structural requirements are concerned, other standards shall be used.

Part A — Arc Welding

2. General Provisions for Arc Welding

2.1 Base Metal

2.1.1 Base metals to be joined under this Code shall include carbon steel, low alloy steel, chromium and chromium-nickel steel alloys, aluminum and aluminum

alloys, copper and copper alloys, nickel and nickel alloys, and coated metals.

2.1.2 Rust inhibitive coatings, galvanized coatings, or anti-spatter compounds may remain on the metal to be joined. (See section 12, Safety and Health, and Appendix J for safety precautions.)

2.2 Filler Metal

2.2.1 Filler metals shall be compatible with the base metal designated on the drawings or specified by the Engineer.

2.2.2 Suggested filler metals are listed in Appendix A.

2.3 Processes. Joining processes under this Code shall include shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), plasma arc welding (PAW), and carbon arc welding (CAW). Other processes may be used, provided they are qualified to the requirements of this Code.

2.4 Terms and Definitions

2.4.1 Terms and definitions shall be interpreted in accordance with the latest edition of ANSI/AWS A3.0, *Standard Welding Terms and Definitions*.

2.4.2 Supplemental definitions (marked with an asterisk) and terms of significant importance to sheet metal welding are given in Appendix B.

2.4.3 The Engineer referred to herein is the duly designated person who acts on behalf of the owner in all matters within the scope of this Code.

2.4.4 The contractor designates the party responsible for performing the welding under the Code. The term is used collectively to mean contractor, fabricator, erector, or manufacturer.

2.5 Symbols. Symbols used in this Code shall be in accordance with the latest edition of ANSI/AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.

2.6 Standard Units of Measurement. The values stated in U.S. Customary Units are to be regarded as the standard. The metric (SI) values of U.S. Customary Units are approximate.

3. Arc Welding Procedure Qualification

3.1 Prior Procedure Qualification

3.1.1 This Code does NOT provide prequalified status to any welding procedure for sheet metal.

3.1.2 The Engineer, exercising proper discretion, may accept evidence of previous qualification of specific procedures to be used on work being performed under this Code. All required information shall be recorded on an adequate Procedure Qualification Record (PQR) form similar to that shown in Appendix E.

Welding procedures qualified in accordance with section 2 of ANSI/AWS B2.1-84, *Standard for Welding Procedure and Performance Qualification*, may be used, provided they also meet the requirements of section 3 of this code.

3.2 Required Procedure Qualification Tests

3.2.1 Welding Procedure Specification. Each welding procedure to be used in conjunction with this Code shall be prepared as a Welding Procedure Specification (WPS) to be used in fabrication and installation. The use of a qualified procedure shall be the responsibility of the Contractor. All required information for the WPS shall be recorded on an adequate form similar to that shown in Appendix D.

3.2.2 Typical Joints. Typical joint designs and details of joints are given in Appendix G, Part A, of this Code. Qualification of a groove weld may be used as a qualification of a fillet weld, but not vice versa.

3.2.3 Preparing Joint Chosen for Testing. The chosen joint design shall be prepared as a longitudinal joint between two 3 in. (75 mm) by 6 in. (150 mm) sheets, assembled as one of the designs sketched in Figure 1 or as the actual joint to be used. Qualification testing using the butt joint in Figure 1 shall qualify all groove and fillet weld joint designs.

3.2.4 Welding the Test Joint. The joint shall be welded using the process specified in the WPS (3.2.1).

3.3 Limitations of Procedure Qualifications. A qualified welding procedure shall be used only within the

range of operating variables tested during qualification. These limits of essential variables are described in the following paragraphs. The variables shall be recorded on an adequate PQR form similar to that shown in Appendix E.

3.3.1 Base Metal. A change from one of the following base metal groups to another, or a change to a weld between dissimilar metals requires separate qualification.

- (1) Carbon steel with 0.30 percent maximum carbon and 0.50 percent maximum chromium
- (2) High-strength, low alloy steels
- (3) Chromium and chromium-nickel steels
- (4) Copper and copper alloys
- (5) Nickel and nickel alloys
- (6) Aluminum and aluminum alloys

3.3.2 Coating Material. The addition or change, but not deletion, of coating material on the base metal requires requalification. (Note: Anti-spatter compound is not considered a coating material.)

3.3.3 Base Metal Thickness

(1) A change in thickness to less than 0.5t or to greater than 2t, where t is the thickness of the thinner base metal qualified requires requalification.

(2) As an alternate to 3.3.3(1), the following qualification tests may be used to cover the complete range of all sheet metal thicknesses as defined in Appendices B and C.

(a) A qualification weld performed on 18 gauge metal shall provide qualification for that procedure for metal 16 gauge and thinner. (See Appendix C for Equivalents.)

(b) A qualification weld performed on 10 gauge metal shall provide qualification for that procedure for metal as thin as 16 gauge and thicker, up to 2t, where t is the thickness of the thinner base metal qualified. (See Appendix C for Equivalent.)

(c) Procedures qualified under (a) and (b) also qualify fillet welds for all thicknesses of base metal.

3.3.4 The omission, but not the addition, of backing material requires requalification.

3.3.5 A change in filler metal "F" number requires requalification (see Appendix A, Table A1)

3.3.6 A change in welding process, or a change in the method of application (manual, semi-automatic, automatic) requires requalification.

3.3.7 Changes in the type of welding current, polarity or mode of metal transfer as indicated below, require requalification (Reference to metal transfer applies to GMAW and FCAW):

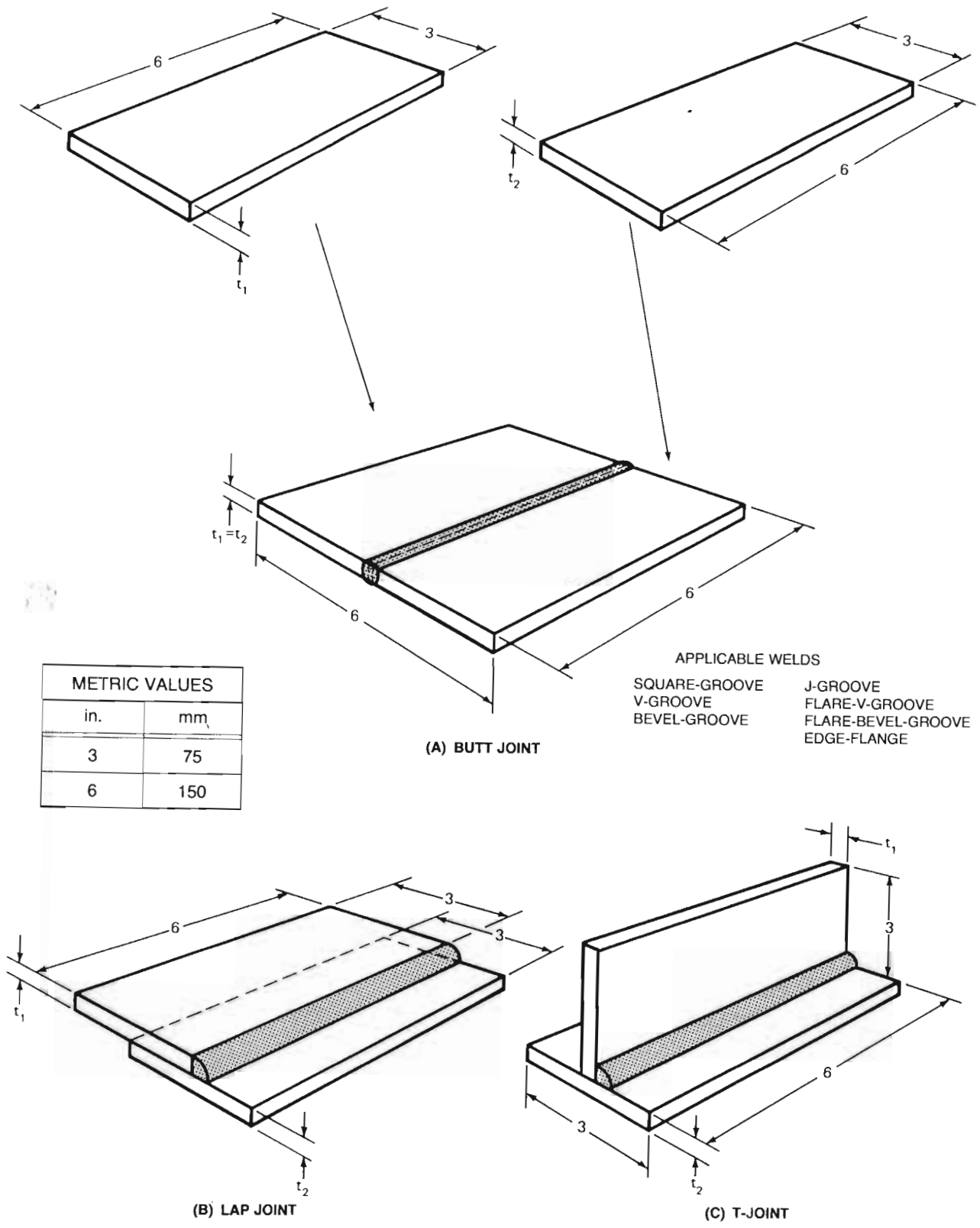


Figure 1 — Procedure Qualification Test Assemblies

- (1) ac to dc or vice versa
- (2) dcen to dcep or vice versa
- (3) short circuiting to globular or spray transfer, or vice versa

3.3.8 A change in shielding gas requires requalification.

3.3.9 Requalification is required when the welding position (Figures 2 and 3) is changed except as noted below:

- (1) Qualification in the flat position shall qualify the procedure only in the flat position.
- (2) Qualification in the horizontal position shall qualify the procedure in both the flat and horizontal positions.
- (3) Qualification in the vertical position shall qualify the procedure in the flat, horizontal and vertical positions.
- (4) Qualification in the overhead position shall qualify the procedure in all positions.

3.4 Inspection of Procedure Qualification Test Welds. Inspection of all test welds shall be visual without aid of magnification (prescription eyeglasses for vision correction are acceptable).

3.4.1 Groove Welds. Except for the first and last 0.5 in. (13 mm), the weld [(Figure 1 (A))] shall exhibit the following:

- (1) Complete fusion.
- (2) Complete joint penetration.
- (3) A maximum of 1/8 in. (3.2 mm) face reinforcement and 1/8 (3.2 mm) root reinforcement.
- (4) No more than one visible pore or inclusion in any 1 in. (25 mm) of weld. Size of any pore or inclusion shall not exceed 0.25t, where t is the base metal thickness.
- (5) No undercut exceeding 0.15t, where t is the base metal thickness being welded.
- (6) No cracks.

3.4.2 Fillet Welds. Except for the first and last 0.5 in. (13 mm), welds shown in Figure 1 (B) and (C) shall exhibit the following:

- (1) Complete fusion.
- (2) The minimum effective throat shall be as specified for the application with maximum convexity not to exceed 1/8 in. (3.2 mm).
- (3) No more than one visible pore or inclusion in any 1 in. (25 mm) of weld. Size of any pore shall not exceed 0.25t, where t is the thickness of the thinner member.
- (4) No undercut exceeding 0.15t when the base metal being welded is 0.187 in. (4.8 mm) or thinner, nor exceeding 0.25t when the base metal thickness being welded is greater than 0.187 in. (4.8 mm).
- (5) No cracks.

3.5 Responsibility for Test

3.5.1 The Contractor performing work in accordance with this Code shall be responsible for qualification of the welding procedures to be used. However, to avoid duplication of effort and subject to the approval of the Customer, welding procedures qualified by a technically competent group or agency may be used, subject to the following conditions:

- (a) The welding procedure specification shall meet all of the procedure qualification requirements of this Code.
- (b) The Contractor shall accept the procedure thus qualified.
- (c) The Contractor shall qualify at least one welder to the procedure.
- (d) The Contractor shall assume specific responsibility for the procedure qualification work done by signing and dating the Welding Procedure Specification.

3.5.2 Records of welding procedures qualified in accordance with this Code shall be maintained by the Contractor and shall be available for inspection as required by the Engineer (see Appendices D and E for suggested forms).

3.6 Duration of Procedure Qualification

3.6.1 Welding procedures qualified under this Code and previous editions of AWS D9.1 superseded by this Code, shall remain qualified until a revision of the Code requires requalification.

3.6.2 Procedures shall be requalified whenever a change is made in an essential variable.

4. Qualification of Arc Welders and Arc Welding Operators

4.1 Prior Welder and Welding Operator Qualification

4.1.1 The Engineer, exercising proper discretion, may accept evidence of previous qualification of welders and welding operators to be used on work being performed under this Code.

4.1.2 Welders and welding operators performing procedure qualification test welds meeting the procedure qualification acceptance criteria in section 3, Arc Welding Procedure Qualification, shall be considered as qualified to perform welding without additional qualification testing, subject to the limitations defined in 4.3.

4.2 Required Welder and Welding Operator Qualification Tests

4.2.1 General. All welders and welding operators permitted to weld under this Code shall be qualified by test.

4.2.2 Groove Welds in a Butt Joint. Test coupon dimensions and test positions for qualification of groove welds in a butt joint are given in Figure 2.

4.2.3 Fillet Welds. Qualification for fillet welds is automatically granted to welders and welding operators who qualify for a groove weld in a butt joint (Figure 2). Either a lap joint fillet or a T-joint fillet may be welded at the option of the contractor unless otherwise specified in the WPS. Test positions for qualification for fillet welds are given in Figure 3.

4.3 Limitations of Welder and Welding Operator Qualifications. The limits of essential variables governing welder and welding operator qualification are described in the following paragraphs.

4.3.1 Base Metal. A change from one of the following base metal groups to another, or a change to a weld between dissimilar metals requires separate qualification.

- (1) Carbon steels with 0.30 percent maximum carbon and 0.50 percent maximum chromium
- (2) High-strength, low alloy steels
- (3) Chromium and chromium-nickel steels
- (4) Copper and copper alloys
- (5) Nickel and nickel alloys
- (6) Aluminum and aluminum alloys

4.3.2 Coating Material. The addition or change, but not deletion, of coating material on the base metal requires requalification. (Note: Anti-spatter compound is not considered a coating material.)

4.3.3 Base Metal Thickness

(1) A change in base metal thickness to less than 0.5t or to greater than 2t, where t is the thickness of the thinner base metal qualified requires requalification.

(2) As an alternate to 4.3.3 (1), the following qualification tests may be used to cover the complete range of all sheet metal thickness as defined in Appendix B and C.

(a) A qualification weld performed on 18 gauge metal shall provide qualification for that welder or welding operator for metal 16 gauge and thinner. (See Appendix C for Equivalents.)

(b) A qualification weld performed on 10 gauge metal shall provide qualification for that welder and welding operator, for metals as thin as 16 gauge and thicker, up to 2t thickness, where t is the thickness of the thinner base metal qualified. (See Appendix C for Equivalents.)

(c) Welders qualified under (a) and (b) are qualified to make fillet welds on all thicknesses of base metal.

4.3.4 The omission, but not the addition, of backing material requires requalification.

4.3.5 A change in filler metal "F" number requires requalification. (see Appendix A, Table A1.)

4.3.6 A change in welding process, including method of application requires requalification except as listed below.

- (1) Qualification for manual welding also qualifies for semiautomatic and automatic application.
- (2) Qualification for semiautomatic welding also qualifies for automatic, but not for manual application.
- (3) Qualification for automatic welding qualifies for automatic welding only.

4.3.7 Changes in the type of welding current, polarity, or mode of metal transfer as indicated below require requalification. (Reference to metal transfer applies to GMAW and FCAW):

- (1) ac to dc or vice-versa
- (2) dcen to dcep or vice-versa
- (3) short-circuiting to globular or spray transfer, or vice versa

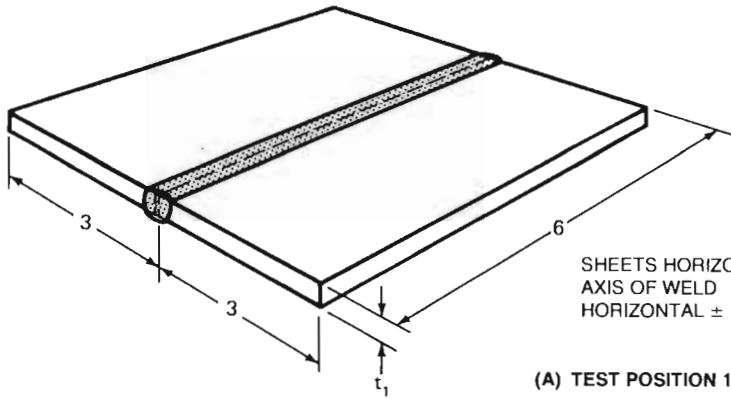
4.3.8 A change in shielding gas requires requalification.

4.3.9 Requalification is required when the welding position (see Figures 2 and 3) is changed except as noted below.

- (1) Qualification in the flat position shall qualify the welder or welding operator only in the flat position.
- (2) Qualification in the horizontal position shall qualify the welder or welding operator in both the flat and horizontal positions.
- (3) Qualification in the vertical position shall qualify the welder or welding operator in the flat, horizontal, and vertical positions.
- (4) Qualification in the overhead position shall qualify the welder or welding operator in all positions.

4.4 Inspection of Welder and Welding Operator Qualification Test Welds. Inspection of all test welds shall be visual without aid of magnification (prescription eyeglasses for vision correction are acceptable). Except for the first and last 0.5 in. (13 mm), welds shall exhibit the following:

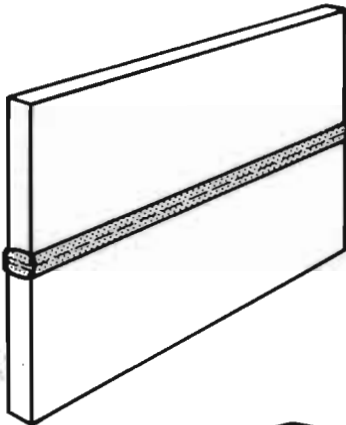
- (1) Complete fusion.
- (2) Complete joint penetration (groove weld in a butt joint) or required minimum effective throat (fillet weld).
- (3) A maximum of 1/8 in. (3.2 mm) face reinforcement and 1/8 in. (3.2 mm) root reinforcement for welds in butt joints or a minimum effective throat equal to the thickness of the thinner member joined with convexity, not to exceed 1/8 in. (3.2 mm) for fillet welds.
- (4) No more than one visible pore or inclusion in any 1 in. (25 mm) of weld. Size of any pore or inclusion shall not exceed 0.25t, where t is the base metal thickness of the thinner member.



(A) TEST POSITION 1G, FLAT

QUALIFICATION IN POSITION 1G QUALIFIES FOR POSITIONS 1G AND 1F (SEE FIG. 3)

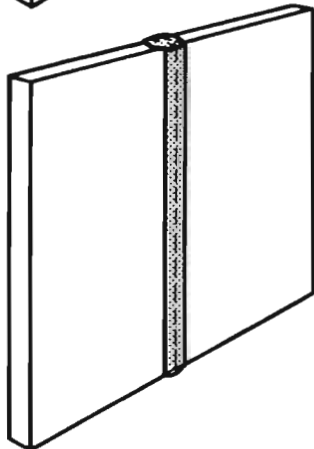
SHEETS HORIZONTAL;
AXIS OF WELD
HORIZONTAL $\pm 15^\circ$



(B) TEST POSITION 2G, HORIZONTAL

QUALIFICATION IN POSITION 2G QUALIFIES FOR POSITIONS 1G, 2G, 1F, AND 2F (SEE FIG. 3)

SHEETS VERTICAL;
AXIS OF WELD
HORIZONTAL $\pm 15^\circ$

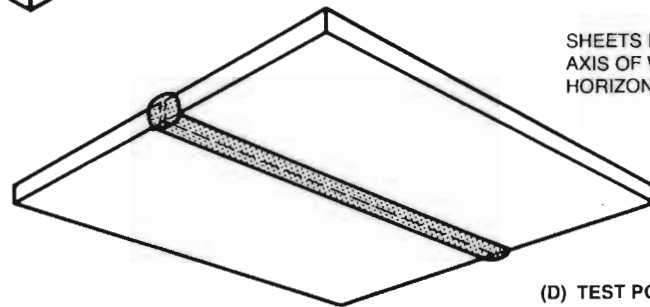


(C) TEST POSITION 3G, VERTICAL

QUALIFICATION IN POSITION 3G QUALIFIES FOR POSITIONS 1G, 2G, 3G, 1F, 2F, AND 3F (SEE FIG. 3)

SHEETS VERTICAL;
AXIS OF WELD
VERTICAL $\pm 15^\circ$

METRIC VALUES	
in.	mm
3	75
6	150

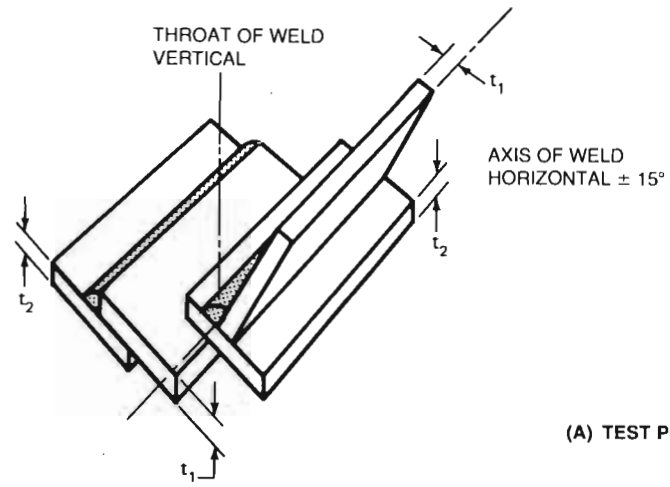


(D) TEST POSITION 4G, OVERHEAD

QUALIFICATION IN POSITION 4G QUALIFIES FOR POSITIONS 1G, 2G, 3G, 4G, 1F, 2F, 3F, AND 4F (SEE FIG. 3)

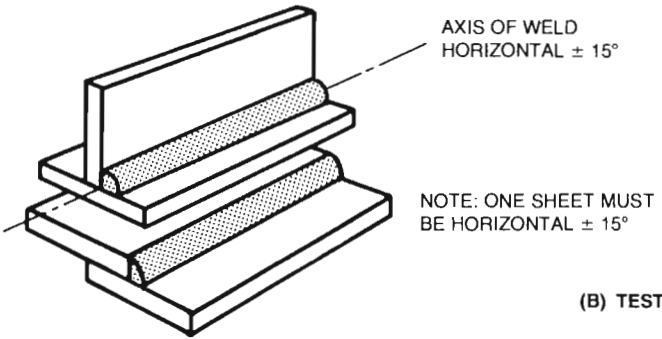
SHEETS HORIZONTAL;
AXIS OF WELD
HORIZONTAL $\pm 15^\circ$

Figure 2 — Butt Joint Groove Weld Test Positions



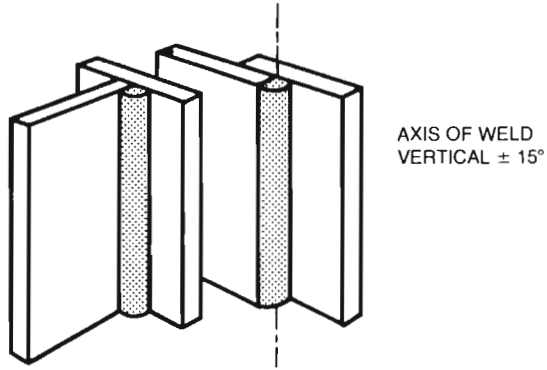
QUALIFICATION IN POSITION 1F QUALIFIES ONLY FOR POSITION 1F

(A) TEST POSITION 1F, FLAT



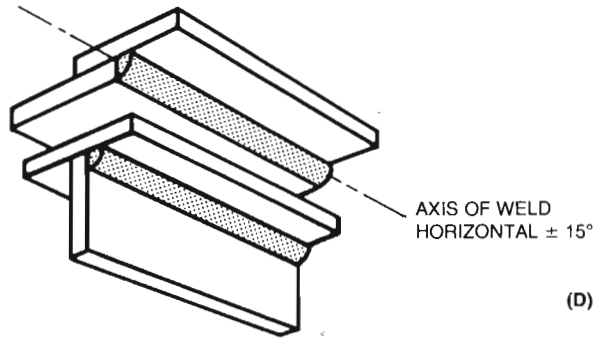
QUALIFICATION IN POSITION 2F QUALIFIES FOR POSITIONS 1F AND 2F

(B) TEST POSITION 2F, HORIZONTAL



QUALIFICATION IN POSITION 3F QUALIFIES FOR POSITIONS 1F, 2F, AND 3F

(C) TEST POSITION 3F, VERTICAL



QUALIFICATION IN POSITION 4F QUALIFIES FOR POSITIONS 1F, 2F, 3F, AND 4F

(D) TEST POSITION 4F, OVERHEAD

Figure 3 — Fillet Weld Test Positions

(5) No undercut exceeding $0.15t$ when the base metal being welded is 0.187 in. (4.8 mm) or thinner in thickness, nor exceeding $0.25t$ when the base metal thickness being welded is greater than 0.187 in. (4.8 mm).

(6) No cracks.

4.5 Responsibility for Tests

4.5.1 The Contractor shall be responsible for the qualification of welders or welding operators in accordance with this Code.

4.5.2 Records of welder or welding operator qualification testing in accordance with this Code shall be maintained by the Contractor and shall be available for inspection as required by the Engineer. All required information for welder or welding operator qualification shall be recorded on an adequate form similar to the recommended form shown as Appendix F.

4.6 Duration of Qualification. Qualification of welders or welding operators tested to the requirements of this Code shall remain in effect unless:

(1) The welder or welding operator ceases to be employed by the Contractor's organization for which original qualification requirements were satisfied.

(2) The welder or welding operator has not been engaged in performing welding operations utilizing the process for which the welder originally qualified for a period exceeding twelve months.

(3) There is a specific reason to question the welder's or welding operator's ability.

5. Arc Welding Workmanship

Work performed under this Code shall exhibit qualities of workmanship described below.

5.1 Uniformity. Surfaces to be joined shall be uniform and free from cracks.

5.2 Cleanliness

5.2.1 Surfaces of, and adjacent to, a joint shall be free of loose scale, rust, grease, or foreign matter.

5.2.2 Tightly adherent spatter is not a cause for rejection.

5.3 Position. If a welding position is not explicitly specified by the Engineer or dictated by job conditions, joints shall be welded in the most favored position for which both the procedure and the welder are qualified (see 3.3.1.9 and 4.3.1.9).

5.4 Current. Welding current and polarity shall be in accordance with the qualified welding procedure.

5.5 Inspection of Workmanship. Welds shall be visually inspected and shall meet the acceptance criteria of section 6.

6. Inspection of Arc Welding Work

Inspection of all production welds shall be visual without aid of magnification (prescription eyeglasses for vision correction are acceptable.)

Acceptance criteria for production welds different from those specified in this Code may be used for a particular application provided they are suitably documented by the proposer and approved by the Engineer.

The Contractor shall conduct inspections to assure conformance to the acceptance criteria. The Engineer, with mutual agreement between the Owner and Contractor, may also conduct inspections of the work to assure conformance to the acceptance criteria. The specified acceptance criteria for the work shall be as follows:

6.1 Fusion. Complete fusion shall be obtained.

6.2 Penetration. Required joint penetration as specified for the application shall be present.

6.3 Reinforcement of Groove Welds. A maximum of 1/8 in. (3.2 mm) face reinforcement and 1/8 in. (3.2 mm) root reinforcement shall be acceptable.

6.4 Throat and Convexity of Fillet Welds. The minimum throat shall be as specified for the application with maximum convexity not to exceed 1/8 in. (3.2 mm).

6.5 Porosity or Inclusions. Some limited porosity or inclusion is acceptable, consistent with 6.1 of this Code and limited to the following:

6.5.1 One visible pore or inclusion no larger than $0.5t$ is permitted in any 1 in. (25 mm) of weld, where t equals the thickness of the thinner member.

6.5.2 Three visible pores or inclusions no larger than $0.25t$ also are permitted in any 1 in. (25 mm) of weld, where t equals the thickness of the thinner member.

6.6 Undercut. Undercut may not exceed $0.15t$ when the base metal thickness being welded is 0.187 in. (4.8 mm) or thinner, or exceed $0.25t$ when the base metal thickness being welded is greater than 0.187 in. (4.8 mm).

6.7 Crack. There shall be no cracks.

6.8 Conformance. Completed welds shall be visually inspected for location, size, and length in accordance with the engineering drawing and specification requirements.