

## **1.0 INTRODUCTION**

### **1.1 SCOPE**

**Appendix W describes AAR requirements for fusion welding on ~~tank heads, shells, sumps~~ tank car tank components and welds attaching connections attached directly thereto. Other welding shall be in accord with the American Welding Society (AWS) Railroad Welding Specification D15.1, latest revision.**

### **1.2 Certified Facilities**

**Fusion welding on tank car tanks shall be performed only by facilities certified by the AAR for fabrication or for alterations, conversions, or welded repairs. See Appendix B.**

### **1.3 Repairs, Alterations and Conversions**

**For repairs, alterations and conversions to tank car tanks, see Appendix R.**

### **1.4 Welding Symbols Mandatory References**

Welding symbols used shall conform to AWS A2.4 (see Figure W21). The welding terms used in this specification shall be interpreted in conformance with the definitions provided in the latest edition of AWS A3.0, *Standard Welding Terms and Definitions*, supplemented by definitions in Chapter 1 of this specification. Welding symbols shall be those shown in the latest edition of AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*.

### **1.5 Weld Sizes and Weld Lengths**

The sizes and lengths of welds shall be no less than those specified by design requirements and detail drawings, except as permitted by 14.6.1.

## **2.0 REQUIREMENTS FOR NONDESTRUCTIVE EXAMINATION**

### **2.1 General**

Tank car tanks, and any attachments welded directly to the tank, must be inspected by NDT examiners qualified per Appendix T for the method employed, in accord with the following paragraphs. For welder visual acuity requirements ~~to check multi-pass welds~~, see paragraphs 14.1 and 14.2.

### **2.2 Tank Shell Joints**

~~2.2.1 For manual and semiautomatic welding procedures, the weld root pass and each layer of multi-pass weld shall be visually checked to make sure they are free from cracks, overlap, incomplete fusion, and inclusions prior to deposition of subsequent passes. The welder making the weld is responsible for this, which shall be monitored by the welding inspector. Inspection of joint fitup, root opening, root face, bevel angles, and visual inspection of partially completed multiple-pass groove and fillet welds shall be done at intervals defined in the facility's in-process inspection plan.~~

~~2.2.2 All completed welded butt joints~~ groove welds shall be visually inspected in accord with paragraph 14.10 ~~below~~ and radiographed examined with UT or RT in accord with paragraph 18.0; ~~also below.~~

### **2.3 Welds Other than Tank Shell Joints—Attachments Welded Directly to the Tank Shell**

~~2.3.1 The root pass and each layer of multi-pass weld shall be visually checked to make sure they are free from cracks, overlap, lack of fusion, and slag inclusions prior to deposition of subsequent weld passes. The welder making the weld is responsible for this, which shall be monitored by the welding inspector. Inspection of joint fitup, root opening, root face, bevel angles, and visual inspection of partially completed multiple-pass groove and fillet welds shall be done at intervals defined in the facility's in-process inspection plan.~~

~~2.3.2 All completed welds shall be visually inspected in accord with paragraph 14.10 below.~~

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

**2.3.3** In addition to the requirements in paragraphs ~~2.3.1~~ 2.2.1 and ~~2.3.2-2.2.2~~, pressure car tank and aluminum tank (pressure and non-pressure) completed fillet welds listed below shall be examined in accord with paragraph 10.0 below. For carbon steel tanks, the completed welds shall be examined by magnetic particle or liquid penetrant, and for aluminum tanks by liquid penetrant. ~~Where practical,~~ The completed welds shall be examined after postweld heat treatment or no sooner than 24 hours after welding.

- Tank anchor pad-to-tank, around the ends of the pad, including at least 3 in. of the longitudinal welds
- Draft sill pad-to-tank, around the outboard end of the pad, including at least 3 in. of the longitudinal welds
- Draft sill pad-to-tank, around the inboard end of the pad, including at least 3 in. of the longitudinal welds, except where pads extend the full length of the tank
- For aluminum tanks only, bolster pad to tank, around the upper end of the pad, including at least 3 in. of the circumferential welds

**2.3.4** Ultrasonic testing of welds may be employed in lieu of magnetic particle or liquid penetrant inspections. Ultrasonic testing of welds shall be performed in accord with the requirements of paragraph 10.0 below.

### **3.0 TEST PLATE REQUIREMENTS**

#### **3.1 General**

**3.1.1** When required by DOT or AAR specifications, test plates shall be prepared, tested, and evaluated in accordance with applicable portions of paragraphs 3.0, 4.0, 5.0, 6.0, and 8.0 below. *Italicized statements*, in paragraphs 3.0 through 8.0, are not applicable to welding procedure qualification.

**3.1.2** *A test plate shall be prepared during fabrication for each WPS used in fabrication of the tank shell.*

**3.1.3** *When more than one welder and/or welding operator welds on a tank, the test plates shall be made by the welder and/or welding operator designated by the fabricator's inspector.*

**3.1.4** A test plate shall be prepared as a part of the qualification requirements for each welding procedure. See paragraph 12.1.2 below.

**3.1.5** *When impact tests are required, the test plate groove details shall be the same as used for the tank fabrication.*

#### **3.2 Longitudinal Joint Test Plates**

**3.2.1** *For each tank having a longitudinal welded joint, a test plate shall be prepared from material of the same specification and thickness as the shell plates of the tank. Test plate material may be taken from any part of one or more plates of the same lot of material that is used in the fabrication of the tank without reference to the direction of mill rolling, except when impact tests are required. When impacts are required, test plates shall be oriented the same as the shell plates with respect to mill rolling and weld directions.*

**3.2.2** *The test plates may be attached to a shell plate being welded, reference Fig. W.1A, so that the weld metal shall be deposited in the test plate continuously with the weld metal deposited in the longitudinal joint.*

**3.2.3** *As an alternative, detached test plates may be prepared, but weld metal shall be deposited using the same WPS used for the longitudinal joints.*

#### **3.3 Circumferential Joint Test Plates**

**3.3.1** *When a test plate is welded for the longitudinal joints of a tank, none need be prepared for circumferential joints in the same tank, provided the same WPS is used for both types of joints.*

**3.3.2** *When the WPS for circumferential joints is different from the one used for longitudinal joints, a detached test plate shall be prepared using the same WPS used for the circumferential joints.*

### **3.4 Straightening of Test Plates**

The test plate shall be supported so that distortion resulting from welding shall not throw the finished test plate out of line by an angle over 5°. Where the welding has distorted the test plate, it shall be straightened before being stress-relieved or heat-treated. Where stress relieving or heat treatment are not specified (aluminum and stainless steel, for example), test plates out of line by an angle over 5° cannot be mechanically flattened. They must be scrapped and the test repeated.

### **3.5 Heat Treatment of Test Plates**

**3.5.1** The test plate shall be subjected to the same postweld heat treatment procedure required in paragraph 16.0 below for the related tank. At no time shall the test plate be heated to a temperature higher than that used for postweld heat treating the related tank.

**3.5.2** *When production test plate impact test specimens are required by DOT or AAR special commodity requirements, the test plate shall be postweld heat treated with its related tank.*

### **3.6 Radiography of Test Plates**

*Test plate welds shall be radiographed full length using technique and acceptance standards of paragraph 10.2 below. If results do not comply with acceptance standards, a new test plate shall be prepared.*

### **3.7 Test Specimens Required**

**3.7.1** *For tanks built of materials listed in Tables M.10.1, M.10.2, M.10.3, M.10.4, M.10.5, M.10.6, and M.10.7, the test plate dimensions shall be sufficient to provide one reduced-section tension specimen conforming to Fig. W.2, Sketch A, plus two guided-bend specimens, either two side-bends, or one face-bend and one root-bend, or one longitudinal face-bend and one longitudinal root-bend.*

**3.7.2** *For tanks built of materials listed in Tables M.10.1, M.10.5, and M.10.7, include sufficient material to provide three impact specimens each of weld metal and heat-affected zone, when required.*

## **4.0 TYPES AND PURPOSES OF TESTS**

### **4.1 Tension, Bend, Macroetch, Hardness, Fillet Tests.**

These types of tests are used to evaluate welding procedure, welder performance, and production welding.

#### **4.1.1 Tension Tests**

- Direct-tension tests are used in welding procedure qualification and production-weld tests.
- Joint-tension specimens are used to measure strength of butt groove-welded joints.
- ~~All weld metal tension specimens are used to measure strength and ductility of weld metal.~~

#### **4.1.2 Guided Bend Tests**

- Guided bend tests are used in welding procedure, welder performance qualification, and production-weld tests.
- Guided bend tests are used to measure soundness and ductility of butt groove-welded joints.

#### **4.1.3 Macroetch Tests**

- Macroetch tests are used in welding procedure, welder performance qualification, and production-weld tests.

- Macroetch tests are used for soundness and weld size measurements in partial penetration groove welds.

#### **4.1.4 Hardness Tests**

- Hardness tests are ~~used in~~ required for qualification of carbon steel pressure tank car tank welding procedures, and production weld qualification tests. See paragraph 8.3.
- *Hardness tests are used to ~~evaluate welding procedure and production welding and to control maximum hardness requirements~~ of repair welds on AHF tank car tanks. See paragraph R4.1.2.*

#### **4.1.5 Fillet Weld Tests**

- Fillet weld tests are sometimes used in welding procedure and welder performance qualification tests to check the size, contour, and penetration of fillet welds and degree of soundness of fillet-welded joints.

### **4.2 Impact Tests**

**4.2.1** Impact tests are used to evaluate welding procedures and production welding when the tank service involves the transportation of low-temperature product.

**4.2.2** Charpy impact tests are used to measure notch toughness, at low temperatures, of weld metal and weld heat-affected zone of ~~butt~~ groove -welded joints.

### **4.3 Radiographic Tests**

**4.3.1** Radiographic examination of a length of weld is used to evaluate the ability of a welding operator to make an acceptable ~~butt~~ groove -welded joint. Under certain conditions, radiographic examination may be used as an alternative to mechanical tests for welder performance qualification.

**4.3.2** Radiographic examination is recommended for welding procedure and production-welded test plates to measure acceptance for preparation of test specimens.

**4.4 Corrosion Tests.** Corrosion tests are used to determine that weld, heat-affected zone, and plate specimens, from test plates made from materials listed in Table M.10.3, are not susceptible to intergranular attack associated with precipitated chromium carbides and meet the acceptable corrosion rates listed in Appendix M, paragraph 3.3.2.

## **5.0 TENSION SPECIMENS AND TESTS**

### **5.1 Joint Tension Specimens**

**5.1.1** Flat, reduced-section tension specimens conforming to requirements of Figure W.2, Sketch A, or turned reduced-section tension specimens conforming to requirements of Figure W.2, Sketch B, may be used for test of welding procedure and production-welded impact test plates. If turned reduced-section tension specimens are used, one complete test set shall be made for each required tension test as given below.

**5.1.2** *For thicknesses to and including 1 1/4 in. (31.8 mm), a single specimen shall be used.*

**5.1.3** *For thicknesses over 1 1/4 in. (31.8 mm), multiple specimens shall be cut through the full thickness of the weld with their centers parallel to the material surface and not over 1 in. (25.4 mm) apart. The centers of the specimens adjacent to material surfaces shall not exceed 5/8 in. (15.9 mm) from the surface.*

### **5.2 Joint Tension Tests**

**5.2.1** Tension test specimens shall be ruptured under tensile load. The tensile strength shall be computed by dividing the maximum load at failure by the least cross-sectional area of the specimen, as measured before load is applied.

**5.2.2** The tensile strength of the specimen shall be not less than:

- The specified tensile strength of the base material as given in Table M.10;
- The specified tensile strength of the weaker of the two, if base materials of different minimum tensile strengths, as given in Table M.10, are used.

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

**5.2.3** If the joint specimen breaks in the base material outside the weld, the test shall be accepted as meeting the requirements, provided the strength is not more than 5% below the specified tensile strength of the base material as specified in Table M.10.

### **5.3—All-Weld-Metal Tension Tests**

**5.3.1**—For the all-weld-metal specimen (the all-weld-metal turned reduced-section test specimen is acceptable), fit the ends of the fractured specimen together carefully and measure the distance between gauge marks to the nearest 0.01 in. (0.254 mm). The elongation is the increase in the length of the gauge length, expressed as a percentage of the original gauge length.

**5.3.1.1**—The elongation shall be not less than the value specified for base material in Table M.10.

**5.3.1.2**—If any part of the fracture takes place outside of the middle half of the gauge length or in a punched gauge mark, the elongation value obtained may not be representative of the material. If the elongation so measured meets the minimum requirements, no further testing is required; but if the elongation is less than the minimum requirements, discard the test and make a retest.

**5.3.2**—The tensile strength shall be not less than:

- The specified tensile strength of the base material as given in Table M.10;
- The specified tensile strength of the weaker of the two, if base materials of different minimum tensile strengths, as given in Table M.10, are used.

## **6.0 BEND SPECIMENS AND TESTS**

### **6.1 Guided-Bend Test Specimens**

**6.1.1** Guided-bend test specimens conforming to requirements of Figure W.3, Sketch B, and Figure W.4 shall be used for qualification tests of welding procedures and welder performance and for production-welded impact test plates.

**6.1.2** Rectangular specimens cut from the test plates are of five types: side-bend, face-bend, root-bend, longitudinal face-bend, and longitudinal root-bend. The cut surfaces shall be designated the “sides” of the specimens. The other two surfaces shall be called “face” and “root”, the “face” having the greater width of weld metal.

### **6.2 Guided-bend Tests**

**6.2.1** Guided-bend specimens shall be bent in test jigs that are substantially in accordance with Figure W.5. Any convenient means may be used to move the plunger member with relation to the die member.

**6.2.2** The specimen shall be placed on the die member of the fixture with the weld at midspan. Face bend specimens shall be placed with the face of the weld directed toward the gap. Root bend and fillet weld soundness specimens shall be placed with the root of the weld directed toward the gap. Side bend specimens shall be placed with that side showing the greater discontinuity, if any, directed toward the gap.

**6.2.3** The specimen at the time of bending shall be between the temperature of 50° F (10° C) and 140° F (60° C). Apply the bending force smoothly without shock, and bend the specimen into the die at a duration no faster than 15 seconds but no slower than 120 seconds by applying a load on the plunger until a 1/8 in. (3.18 mm) diameter wire cannot be inserted between the specimen and any point on the plunger.

**6.2.4** The convex surface of the bend test specimen shall be visually examined for surface discontinuities. For acceptance, the surface shall contain no discontinuities exceeding the following dimensions:

- 1/8 in. (3 mm) measured in any direction on the surface.
- 3/8 in. (10 mm) – sum of the greatest dimensions for all discontinuities exceeding 1/32 in (1 mm), but less than or equal to 1/8 in (3 mm)
- 1/4 in. (6 mm) – maximum corner crack, except when that corner crack resulted from visible slag inclusion or other fusion-type discontinuities, then the 1/8 in. (3 mm) maximum shall apply. The specimens with corner cracks exceeding 1/4 in. (6 mm) with no evidence of slag inclusions or other fusion-type discontinuities may be disregarded, and a replacement test specimen from the original weldment shall be tested.

## **7.0 FILLET WELD SPECIMENS AND TESTS**

**7.1 Fillet Weld (Tee-Joint) Specimens.** T-Joint specimens, when required, shall conform to requirements of Figure W.6

**7.1.1** The fillet weld specimen may be used for qualification test of welder performance and shall be cut to provide a T-joint section for lateral loading and to provide a cross-section of the weldment, to be smoothed and macroetched with a suitable etchant, to give a clear definition of the structure of the weld metal and heat-affected zone, See Figure W.6, Sketch B.

### **7.2 Fillet Weld Tests**

**7.2.1** The T-joint specimens prepared in accordance with Figure W.6, Sketch A shall contain no visible cracks.

**7.2.2** The vertical member of the performance qualification T-joint shall be loaded laterally and the load steadily increased until the specimen fractures or bends flat upon itself. To pass, the specimen shall not fracture; or, if it fractures, the fractured surfaces shall show no evidence of cracks or incomplete root fusion, and the sum of the lengths of open discontinuities visible on the fractured surfaces shall not exceed 2 in. (50.8 mm) for ferrous materials and 3/4 in. (19.0 mm) for nonferrous materials.

**7.2.3** The performance qualification T-joint weld shall have no concavity or convexity greater than 1/16 in. (1.59 mm) and shall have not more than 1/16 in. (1.59 mm) difference in the lengths of the legs of the fillet weld.

**7.2.4** The procedure qualification T-joint weld shall have not more than 1/8 in. (3.18 mm) difference in the lengths of the legs of the fillet weld.

**7.2.5** Visual examination of the macroetched cross sections of the weld metal and heat-affected zones of performance and procedure qualification T-joint welds shall show freedom from cracks and complete fusion at the joint root, but not necessarily beyond the root.

## **8.0 IMPACT, CORROSION AND HARDNESS TESTS**

**8.1 Impact Specimens and Tests.** Impact tests are required only when specified in the tank specification.

**8.1.1 Material and Number Required.** *Test plates used to prepare specimens shall be provided for each tank and shall be from one of the heats that provided plates for the tank. Where welding is involved, the plates shall be welded using the same joint detail, WPS and electrodes as required for the tank. Unless otherwise specified, at least one set of three specimens shall be taken across the weld with notch in the heat-affected zone and one set of three with notch in the weld metal, see Figure W.9. When two plates of different materials are involved, an additional set of three specimens shall be taken so that there is one set with the notch in each heat-affected zone.*

**8.1.2 Type, Location and Orientation of Specimens.** Unless otherwise specified, specimens shall be Type A (10 mm x 10 mm Charpy V-notch), prepared in accordance with Figure W.10. Where the thickness of the plate is not sufficient to permit full-size specimens, the largest subsize possible shall be prepared, maintaining the 10 mm depth of the specimens. The location and orientation of the specimens and their notches shall be as shown in Figure W.9. The heat-affected zone notch shall be located in an area of maximum grain size, as determined by etching the specimen.

**8.1.3 Test Procedure.** Specimens shall be tested in accordance with ASTM E23 at a temperature specified in the tank specification. The following precautions are to be observed:

- Test specimens, as well as the handling tongs, shall be cooled for a sufficient length of time (usually 15 minutes) to reach the test temperature.
- Test temperature shall be maintained within a range of  $\pm 3^{\circ}$  F ( $\pm 1.67^{\circ}$  C).
- Test specimens shall be transferred from cooling medium to the anvil of the test machine and broken within a time lapse of not more than 5 seconds.

### **8.1.4 Test Results and Retests**

**8.1.4.1** Unless otherwise specified in the tank specification, the minimum impact test values of the full-size and sub-size specimens shall be as shown in Table W.1.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

**Table W.1 Minimum Impact Test Values**

Size of Specimen (mm)	Minimum Value		Minimum Value	
	Each of Two of Three Specimens and Average of the Three Specimens		One of the Three Specimens	
	ft-lb	J	ft-lb	J
10 by 10	15	20.3	10	13.6
10 by 7.5	12.5	16.9	8.5	11.5
10 by 5	10	13.6	7	9.49
10 by 2.5	5	6.78	3.5	4.74

**8.1.4.2** If the value for more than one specimen is below the minimum value specified for the average of the specimens, or if the value for one specimen is below the minimum value specified for one of the three specimens (the other two being not less than the minimum value specified for the average of the three specimens), a retest of three additional specimens shall be made, each of which must be equal or exceed the specified minimum value for the average of three specimens. Such a retest shall be permitted only when the average value of the three specimens equals or exceeds the minimum value specified for one of the three specimens.

**8.1.4.3** If the required values are not obtained upon retest, or if the values on the initial test are below the minimum required for retest, the welding procedure and/or weld metal as the case may be shall be rejected.

**8.1.4.4** When an erratic result is caused by a defective specimen, or there is uncertainty in the test procedure, a retest shall be allowed.

**8.1.5 Reports**

**8.1.5.1** A report of impact test results shall include identity of plate material (specification, grade, and heat number), PQR, and welding electrodes; type and size of impact test specimens; location and orientation of specimens and notches with respect to place surface and rolling direction; and weld metal and weld heat-affected zone impact value for each specimen.

**8.1.5.2** *The complete report of all impact tests shall be retained for not less than 5 years by the tank fabricator, or by the car owner if the owner so requests.*

**8.2 Corrosion Specimens and Tests.** Corrosion tests are required on tanks fabricated from materials listed in Table M.10.3 when required by the tank specification.

**8.2.1 Material and Number Required.** *Test plates used to prepare specimens shall be provided from each heat of material used to fabricate tanks and each heat of filler metal that is used to weld tanks. Where welding is involved, the plates shall be welded using the same WPS as used on the tank. At least one set of three specimens shall be taken from the test plate, located as shown in Figure W.1, Sketch B. Corrosion testing of the base metal is not a requirement if the corrosion test has been conducted and certified by the material supplier. Specimens shall be tested in accordance with ASTM A262 Practice A. If the results of Practice A are unacceptable, further testing with Practice B or C is required.*

**8.2.2 Test Criteria**

**8.2.2.1** Corrosion test specimens shall be considered to be acceptable when each exhibits corrosion rates not in excess of those listed in Appendix M, paragraph 3.3.2.

**8.2.2.2** Weld corrosion test specimens need not be sensitized.

**8.2.3 Reports**

**8.2.3.1** A report of corrosion test specimens shall include identity of plate material (specification, grade, and heat number), welding procedure, welding electrodes, and corrosion rate for each specimen tested.

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

**8.2.3.2** *The complete report of all corrosion tests shall be retained for not less than 5 years by the tank fabricator, or by the car owner if the owner so requests.*

**8.3 Hardness Test.** Hardness tests of production butt welds are required for pressure tank cars fabricated from materials listed in Table M.10.1. Hardness tests are required for qualification of welding procedures used to join pressure tank car tank sections fabricated from materials listed in Table M.10.1. Vickers hardness readings for center of weld (CW) and heat-affected zone (HAZ) shall be taken in accordance with ASTM E384 and Figure W.22 of this appendix. If another method of hardness is to be used, the equivalent hardness number shall be determined from ASTM E140.

**8.3.1** On each tank, at least three points inside and three points outside shall be checked at the centerline of the welds. Two of the inside points and two of the outside points shall be at intersections of longitudinal and circumferential butt welds. Grind the weld metal to produce a flat surface for hardness testing at these check points. Do not grind weld reinforcement below joining plate surface. Hardness of weld shall not exceed 238 DPH (Diamond Pyramid Hardness) or 20 HRC (Rockwell C) after post weld heat treatment. Heat-affected zone hardness shall not exceed 270 DPH or 26 HRC after post weld heat treatment.

**8.3.2** Hardness of weld shall not exceed Brinell 225 (Rockwell C20) after post weld heat treatment.

**8.3.3** Hardness tests of butt welds on multi-unit tank car tanks shall be performed on exterior weld seams only. One test per weld procedure is required on each tank.

**8.4 Macroetch Test.** Macroetch tests are used for soundness and weld size measurements in partial penetration groove welds and fillet welds. For acceptable qualification, the test specimens, when inspected visually, shall conform to the following requirements:

**8.4.1** Partial joint penetration groove welds shall have the designated effective weld size.

**8.4.2** Fillet welds shall have fusion to the root of the joint but not necessarily beyond.

**8.4.3** Minimum leg size shall meet the specified fillet weld size and shall not exceed the specified size by more than 1/8 in (3 mm).

**8.4.4** The partial joint penetration groove welds and fillet welds shall have the following:

- No cracks, incomplete fusion, or porosity.
- No undercut exceeding 1/64 in.
- Complete fusion between adjacent layers of weld metal and between weld metal and base metal.]
- Weld profiles conforming to intended detail.

## **9.0 PROCEDURE AND PERFORMANCE QUALIFICATION**

### **9.1 Scope**

The rules of paragraphs 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, and 12.0 in this appendix apply to qualification of welding procedures, welders, and welding operators ~~of for all types of~~ welding processes covered by this specification. This does not preclude the use of other welding processes in the construction, alteration, or repair of tank car tanks. However, the requirements for the design, qualification, inspection, and testing related to the use of such processes are the responsibility of the certified facility. The certified facility electing to use such processes shall generate documented evidence in conformance with a nationally recognized standard to substantiate their use and to define the essential variables. The supporting documented evidence shall be submitted to the AAR Tank Car Committee for approval.

### **9.2 Responsibility**

**9.2.1** Each company shall be responsible for the Welding Procedure Specifications (WPS) used by the company and their subcontractors. The company or subcontracted employer shall conduct the tests required by this appendix to qualify the Welding Procedure Specifications (WPS) used in the construction of the weldments built under this specification and the performance of welders and welding operators who apply these procedures.

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

9.2.2 When a company changes ownership, the new company shall review the Procedure Qualification Records (PQR), Welding Procedure Specifications (WPS) and performance qualifications of welders and welding operators to determine whether they conform to the requirements of this specification.

9.2.2.1 The Procedure Qualification Record (PQR) shall be revised to reflect the name of the new company. The revision shall maintain record of original company performing said qualification.

9.2.2.2 A properly documented WPS that does conform to the provisions of this specification may be used without requalification provided that the new company accepts responsibility for it and that the WPS is revised to reflect the name of the new company.

9.2.2.3 Welders and welding operators whose qualification records do conform to the provisions of this specification may continue to weld without requalification provided that the new company accepts responsibility for their qualification and that their qualification records reflect the name of the new company. The revision shall maintain record of original company performing said qualification.

9.2.3 Procedure and performance qualifications that were performed to and met the requirements of earlier editions of this specification while those editions were in effect are valid and may be used provided the requirements of the current edition are still met.

9.2.4 Each company shall ensure that welders are trained and qualified in the areas of welding symbols, welding procedures, acceptance criteria, and other sections of this specification applicable to their work. The training shall be documented.

9.2.5 Welding performed by a certified company's subcontracted employer may be used to fabricate, alter, repair or convert tank car tanks in accordance with this specification, provided all the requirements of this specification are met and the certified company takes responsibility for all welding. The extent of the subcontracted employers welding operations shall be clearly discernable.

### **9.3 Records**

9.3.1 Each company shall maintain records of Welding Procedure Specification (WPS) for each of its qualified welding procedures, the supporting Procedure Qualification Records (PQR) and the performance qualification of its welders and welding operators. These records shall be certified by a responsible official of the company by means of a signature and date of when certified. These records shall be available to those authorized to examine them. Companies may centralize the storage of these records.

9.3.1.1 Recommended forms for these records are shown in Figures W.11, W.12, and W.13.

### **9.4 Identification of Welds**

9.4.1 Each qualified welder and welding operator shall be assigned a unique identifying number, letter or symbol by the company. The assigned identification shall be used to identify the work of that welder or welding operator.

### **9.5 Qualification Restrictions**

9.5.1 Facilities shall use AAR-qualified welders and welding operators. ASME performance qualification for plate materials listed in Appendix M, paragraph 3.0, may be accepted as meeting this requirement. Radiography used for ASME performance qualification must be in accordance with Appendix W. Completed test plate assemblies must be visually inspected in accordance with paragraph 14.10 below and with paragraph 14.5 or paragraph 14.6, also below, as applicable.

9.5.2 The qualification of the procedure, welders and welding operators utilized by the company shall be under the full supervision and control of the company. Each company shall qualify the welding procedures, welders and welding operators used to produce welds meeting this appendix. A Procedure Qualification Record (PQR) from one company shall not be used to qualify a Welding Procedure Specification (WPS) for another company.

9.5.2.1 An exception to the requirements of 9.5.2 is allowed when one certified company (*company A*) contracts with another certified company (*company B*) to perform welding on equipment they own. In this instance the certified company (*company B*) performing the welding may elect to utilize the certified car owner's

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

(company A's) WPS in performance of the welding. Both companies shall agree to such an exception and all other requirements of this specification pertaining to the qualification of welding shall be met

**9.5.3** The welding of the test specimens to produce a Procedure Qualification Record (PQR) cannot be subcontracted.

**9.5.4** It is permissible to subcontract the preparation of test materials for welding, preparation of test specimens from completed weldments, nondestructive examination, and mechanical testing, provided the certified company accepts full responsibility for any such work.

## **9.6 Weld Orientation and Test Positions**

**9.6.1** All welds used in actual production shall be classified as: (1) flat, (2) horizontal, (3) vertical, (4) overhead in accordance with the definitions of welding positions given in paragraphs 9.6.2 through 9.6.5 below and in Figure W.7 and Figure W.8.

**9.6.2 Groove Plate Test Welds (Figure W.14.a).** In making the tests to qualify groove welds, test plates shall be welded in at least one of the following positions:

**9.6.2.1 Position 1G (Flat).** The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side.

**9.6.2.2 Position 2G (Horizontal).** The test plates shall be placed in an approximately vertical plane with the groove approximately horizontal.

**9.6.2.3 Position 3G (Vertical).** The test plates shall be placed with the groove approximately vertical.

**9.6.2.4 Position 4G (Overhead).** The test plates shall be placed in an approximately horizontal plan and the weld metal shall be deposited from the underside.

**9.6.2.5** A manufacturer who does production welding in a special orientation may make a groove plate test weld for procedure qualification in that specific orientation. Such qualifications are valid only for the positions actually tested, except for the following:

(1) For other than vertical position test welds (Figure W.8), an angular deviation of  $\pm 15^\circ$  is permitted in the inclination of the weld axis and the rotation of the weld face.

(2) Vertical position test welds qualify all vertical positions of lesser inclination.

**9.6.3 Groove Pipe Test Welds (Figure W.14.b).** In making the tests to qualify groove welds, test pipe shall be welded in the following positions:

**9.6.3.1 Position 1G (Pipe Horizontal Rolled).** The test pipe shall be placed with its axis horizontal and the groove approximately vertical. The pipe shall be rotated during welding so the weld metal is deposited from the upper side.

**9.6.3.2 Position 2G (Pipe Vertical Fixed).** The test pipe shall be placed with its axis vertical and the welding groove approximately horizontal. The pipe shall not be rotated during welding.

**9.6.3.3 Position 5G (Pipe Horizontal Fixed).** The test pipe shall be placed with its axis horizontal and the groove approximately vertical. The pipe is not rotated during welding.

**9.6.3.4 Position 6G (Pipe Inclined Fixed).** The test pipe shall be inclined at  $45^\circ$  with the horizontal. The pipe is not rotated during welding.

**9.6.3.5** A manufacturer who does production welding in a special orientation may make groove pipe test weld for procedure qualification in that specific orientation. Such qualifications are valid only for the position actually tested, except that the angular deviation of  $\pm 15^\circ$  is permitted in the inclination of the pipe axis.

**9.6.4 Fillet Welds in Plate (Figure W.15.a).** In making the tests to qualify fillet welds, test plates shall be welded in the position outlined below:

**9.6.4.1 Position 1F (Flat).** The test plates shall be so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical.

**9.6.4.2 Position 2F (Horizontal).** The test plates shall be so placed that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**9.6.4.3 Position 3F (Vertical).** The test plates shall be so placed that each fillet weld is deposited with its axis approximately vertical.

**9.6.4.4 Position 4F (Overhead).** The test plates shall be so placed that each fillet weld is deposited on the underside of the horizontal surface and against the vertical surface.

**9.6.4.5** A manufacturer who does production welding in a special orientation may make fillet plate test welds for procedure qualification in that specific orientation. Such qualifications are valid only for the positions actually tested, except for the following:

(1) For other than vertical position test welds (Figure W.7), an angular deviation of  $\pm 15^\circ$  is permitted in the inclination of the weld axis and the rotation of the weld face.

(2) Vertical position test welds qualify all vertical position fillet welds of lesser inclination.

**9.6.5 Fillet Welds in Pipe (Figure W.15.b).**

**9.6.5.1 Flat Position 1F.** The test pipe shall be placed with its axis inclined at  $45^\circ$  to the horizontal and rotated during welding. The weld metal is deposited from above so that at the point of deposition, the axis of the weld is horizontal and the weld size vertical.

**9.6.5.2 Horizontal Positions 2F and 2FR**

**9.6.5.2.1** The position 2F test pipe shall be placed with its axis vertical so that the weld is deposited on the upper side of the horizontal surface and against the vertical surface. The axis of the weld shall be horizontal and the pipe is not rotated during welding.

**9.6.5.2.2** The position 2FR test pipe shall be placed with its axis horizontal and the axis of the deposited weld in the vertical plan. The pipe is rotated during welding.

**9.6.5.3 Overhead Position 4F.** The test pipe shall be placed with its axis vertical so that the weld is deposited on the underside of the horizontal surface and against the vertical surface. The axis of the weld shall be horizontal and the pipe is not rotated during welding.

**9.6.5.4 Multiple Position 5F.** The test pipe shall be placed with its axis horizontal and the axis of the deposited weld in the vertical plan. The pipe is not rotated during welding.

**9.6.6** A manufacturer who does production welding in a special orientation may make fillet pipe test welds for procedure qualification in that orientation. Such qualifications are valid only for the position tested, except that an angular deviation of  $\pm 15^\circ$  is permitted in the inclination of the pipe axis.

**9.6.7** Performance qualification in one of the above positions shall permit welding within the range of orientation specified for that position in accordance with Table W.2 and as shown in Figures W.7 and W.8.

**9.6.8** Welders who pass the required groove or fillet weld tests listed in paragraphs 9.6.2, 9.6.3, 9.6.4 or 9.6.5 shall be qualified for the positions of groove welds and fillet welds as shown in Table W.2.

**Table W.2 Performance Qualification – Position Limitations <sup>a/</sup>**

Qualification Test <sup>b/</sup>		Production Weld Type and Position Limitation <sup>c/</sup>			
		Plate, Structural Shapes, Box Tubing and Pipe over 24 inches (610mm) in Diameter		Pipe 24 inches (610mm) and under in Diameter	
Weld Type	Position	Groove	Fillet	Groove	Fillet <sup>e/</sup>
Plate-Groove	1G	F	F, H	---	F,H
	2G	F, H	F, H	---	F, H
	3G	F, V	F, V	---	F, V
	4G	F, OH	F, OH	---	F, OH
	2G, 3G, 4G	All	All	---	All
Plate-Fillet <sup>d/</sup>	1F	---	F	---	F

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

	2F	---	F, H	---	F, H
	3F	---	F, V	---	F, V
	4F	---	F, OH	---	F, OH
	2F, 3F, 4F	---	All	---	All
Pipe-Groove 24 inches (610mm) and under in Diameter	1G Rotated	F, H	F, H	F	F, H
	2G	F, H	F, H	F, H	F, H
	5G	F, V, OH	F, V, OH	F, V, OH	F, V, OH
	6G	All	All	All	All
	2G and 5G	All	All	All	All
Pipe-Fillet 24 inches (610mm) and under in Diameter	1F Rotated	---	F	---	F
	2F/ 2FR	---	F, H	---	F, H
	4F	---	F, OH	---	F, OH
	5F	---	All	---	All

<sup>a</sup> For thickness and diameter range qualified, see Table W.6.

<sup>b</sup> For welding test positions see Figures W.14, W.15 and W.XX for pipe.

<sup>c</sup> For production welding positions, see Figures XXX and XXX; F=flat; H=horizontal; V=vertical; OH=overhead

<sup>d</sup> Not applicable for connections having a dihedral angle of less than 60°

<sup>e</sup> Includes socket welded fittings.

**9.6.9** A company that does fabrication, repair, alteration, or conversion in a particular position may make the tests in that position, but such a performance qualification is valid only for the flat position and for the position actually tested, except an angular deviation of  $\pm 15^\circ$  is permitted in the inclination of the weld axis and the rotation of the weld face as defined in Figures W.7 and W.8.

## 10.0 NONDESTRUCTIVE EXAMINATIONS AND ACCEPTANCE STANDARDS

### 10.1 Scope

These paragraphs define the acceptance criteria and personnel qualifications that shall be used whenever nondestructive test methods are required by this specification or in a tank specification. Acceptance criteria for nondestructive testing are described in the following paragraphs:

- ~~Radioseopy~~ Radiography, paragraph 10.2
- Liquid penetrant, paragraph 10.3
- Magnetic particle, paragraph 10.4
- Ultrasonic examination, paragraph 10.5

### 10.2 ~~Radioseopic~~ Radiographic Acceptance Criteria

#### 10.2.1 General

**10.2.1.1** A detailed procedure for the radiographic examination of welded joints shall be established in accord with Appendix T by each facility.

**10.2.1.2** A Level II or Level III NDT technician, qualified in accord with Appendix T for radiographic testing, shall review and approve all required radiographic examinations.

#### 10.2.2 Acceptance Standards for Radiographed Welds

**10.2.2.1** Reference radiographs of ASTM E390, "Reference Radiographs for Steel Fusion Welds," are accepted as a guide to types and degrees of discontinuities detectable by radiographs of steel

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

welds.

**10.2.2.2** Radiographs of welds whose radiotapes that show any of the following types of discontinuities imperfections shall be unacceptable:

- An elongated slag inclusion that has a length greater than 1/4 in. (6.35 mm) for T up to 3/4 in. (19.0 mm), or 1/3 T for T from 3/4 in. to 2 1/4 in. (19.0 mm to 57.2 mm) (T is thickness of the thinner plate of the joint)
- A group of slag inclusions in line that have an aggregate length greater than T in a weld length of 12T, except when the distance between successive inclusions exceeds 6L, where L is the length of the longest inclusion in the group
- Any type of crack or zone of incomplete fusion or incomplete penetration
- Rounded indications in excess of that specified as acceptable in paragraphs 10.2.3 and 10.2.4 below.

**10.2.3 Rounded Indications**

**10.2.3.1** Images of a general circular or oval shape shall be interpreted as rounded indications for the purpose of this standard. For radiography, the image will appear dark. For fluoroscopy, the image will appear light. Permissible rounded indications are those with a length equal to or less than three times the width. Rounded indications may be circular, conical, or irregular in shape and may have tails. When evaluating the size of an indication, the tail shall be included.

**10.2.3.2** Rounded indications for weld thicknesses intermediate to those illustrated shall be evaluated by comparison with rounded indications chart for the next thinner material or by calculation as shown in Table W.3.

**10.2.3.3** The total area of the rounded indications as determined from the radiograph shall not exceed  $0.060T \text{ in.}^2$  ( $38.7T \text{ mm}^2$ ) in any 6 in. (152 mm) length of weld, where T is the thickness of the weld. If the weld is less than 6 in. (152 mm) long, the total area of rounded indications will be reduced in proportion.

**10.2.3.4** In any 1 in. (25.4 mm) length of weld or 2T, whichever is smaller, rounded indications may be clustered to a concentration four times that permitted by  $0.060T \text{ in.}^2$  ( $38.7T \text{ mm}^2$ ). Such clustered rounded indications shall be included in the rounded indications in any 6 in. (152 mm) length of weld that includes the cluster.

**10.2.3.5** Aligned rounded indications shall be acceptable provided the summation of the diameters of the indications is no more than T in a length 12T or 6 in. (152 mm), whichever is less, provided each indication is separated by a distance at least six times the diameter of the largest adjacent indication. Aligned rounded indications shall be counted in the total area of permissible indications in any 6 in. (152 mm) length of weld.

**10.2.3.6** The maximum indication dimension shall be 0.2T or 1/8 in. (3.18 mm), whichever is smaller, except that an isolated indication separated from an adjacent indication by 1 in. (25.4 mm) or more may be 0.3T or 1/4 in. (6.35 mm), whichever is less.

**Table W.3 Maximum permissible rounded indications in radiographs per 6 in. length of weld—conventional units**

Weld Thickness, in.	Total Area of Permitted Indications, in. <sup>2</sup>	Large Indication Size			Medium Indication Size			Fine Indication Size		
		Approx. Fraction, in.	Decimal Value, in. <sup>a/</sup>	No.	Approx. Fraction, in.	Decimal Value, in. <sup>a/</sup>	No.	Approx. Fraction, in.	Decimal Value, in. <sup>a/</sup>	No.
1/4	0.015	—	—	—	3/128	0.025	31	1/64	0.0138	100
1/2	0.030	3/32	0.10	4	1/32	0.031	40	3/128	0.0195	101

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

3/4	0.045	1/8	0.125	4	1/32	0.034	50	3/128	0.024	99
1	0.060	1/8	0.125	5	5/128	0.039	50	1/32	0.0275	101
1 1/2	0.090	1/8	0.125	7	3/64	0.048	50	1/32	0.034	99
2	0.120	1/8	0.125	10	7/128	0.055	51	5/128	0.039	100

<sup>a/</sup> These values used for calculating total area of permitted rounded indications.

**Table W.4 Maximum permissible rounded indications in radiographs per 15.2 mm length of weld—SI units**

Weld Thickness, mm	Total Area of Permitted Indications, mm <sup>2</sup>	Large Indication Size		Medium Indication Size		Fine Indication Size	
		Decimal Value, mm <sup>a/</sup>	No.	Decimal Value, mm <sup>a/</sup>	No.	Decimal Value, mm <sup>a/</sup>	No.
6.35	9.68	—	—	0.64	31	0.351	100
12.7	19.4	2.54	4	0.79	40	0.495	101
19.0	29.0	3.18	4	0.86	50	0.610	99
25.4	38.7	3.18	5	0.99	50	0.699	101
38.1	58.1	3.18	7	1.22	50	0.864	99
50.8	77.4	3.18	10	1.40	51	0.991	101

<sup>a/</sup> These values used for calculating total area of permitted rounded indications.

**10.2.4 Rounded Indication Charts**

The rounded indication charts, Figs. W.16 through W.19, illustrate various types of assorted and uniform, randomly dispersed rounded indications. The chart for each thickness represents the maximum acceptable rounded indication. The charts represent full-scale 6 in. radiographs and shall not be enlarged or reduced. The rounded indication distributions shown are not necessarily the patterns that may appear on the radiograph, but are typical of the number and size of indications permitted. When rounded indications differ significantly from the charts, the actual numbers and sizes of the rounded indications may be measured and the total area of rounded indications calculated.

**10.3 Liquid Penetrant Examination Acceptance Criteria**

**10.3.1 General**

~~10.3.1.1 This section describes methods that shall be employed whenever liquid penetrant examination is specified in this specification or in a tank specification. A Level II or Level III NDT technician, qualified in accord with Appendix T for liquid penetrant testing, shall review and approve all required liquid penetrant examinations.~~

**10.3.1.2** Liquid penetrant examination shall be performed in accord with a written procedure qualified by the facility to be in accord with the requirements of Appendix T.

**10.3.2 Evaluation of Indications**

An indication is the evidence of a mechanical imperfection. Only indications with major dimensions greater than 1/16 inch shall be considered relevant.

**10.3.2.1** A linear indication is one having a length greater than three times the width.

**10.3.2.2** A rounded indication is one of circular or elliptical shape with the length equal to or less than three times the width.

**10.3.2.3** Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

### **10.3.3 Acceptance Standards**

**10.3.3.1** These acceptance standards shall apply, unless other more restrictive standards are specified for specific materials or applications within this specification. Any indication that is believed to be nonrelevant shall be regarded as ~~an imperfection~~ a discontinuity, unless it is shown by reexamination, by the same method or by the use of other nondestructive methods and/or by surface conditioning, that no rejectable discontinuity ~~unacceptable imperfection~~ is present.

**10.3.3.2** All surfaces to be examined shall be free of

- relevant linear indications.
- relevant rounded indications greater than 3/16 in.
- four or more relevant rounded indications, in a line, separated by 1/16 in. or less, edge to edge.

## **10.4 Magnetic Particle Examination Acceptance Criteria**

### **10.4.1 General**

**10.4.1.1** A Level II or Level III NDT technician, qualified in accord with Appendix T for magnetic particle testing, shall review and approve all required magnetic particle examinations.

**10.4.1.2** Magnetic particle examination shall be performed in accord with a written procedure qualified by the facility to be in accord with the requirements of Appendix T.

### **10.4.2 Evaluation of Indications**

Indications will be revealed by retention of magnetic particles. All such indications are not necessarily ~~imperfections~~ rejectable discontinuities, however, because excessive surface roughness, magnetic permeability variations (such as at the edge of heat-affected zones), etc., may produce similar indications. These are considered nonrelevant indications.

Only indications that are the result of mechanical imperfection and have any dimension greater than 1/16 in. shall be considered relevant.

**10.4.2.1** A linear indication is one having a length greater than three times the width.

**10.4.2.2** A rounded indication is one of circular or elliptical shape with a length equal to or less than three times its width.

**10.4.2.3** Any questionable or doubtful indications shall be reexamined to determine whether or not they are relevant.

### **10.4.3 Acceptance Standards**

**10.4.3.1** These acceptance standards shall apply, unless other more restrictive standards are specified for specific materials or applications within this specification. Any indication that is believed to be nonrelevant shall be regarded as ~~an imperfection~~ a discontinuity, unless it is shown by reexamination, by the same method or by the use of other nondestructive methods and/or by surface conditioning, that no ~~unacceptable imperfection~~ rejectable discontinuity is present.

**10.4.3.2** All surfaces to be examined shall be free of

- relevant linear indications.
- relevant rounded indications greater than 3/16 in.
- four or more relevant rounded indications, in a line, separated by 1/16 in. or less, edge to edge.

## **10.5 Ultrasonic Examination**

### 10.5.1 General

**10.5.1.1** Ultrasonic examination may be employed in accord with Appendix T for complete penetration groove welds in butt joints on tank car tank components. A detailed procedure shall be established in accord with Appendix T by each facility.

**10.5.1.2** A Level II or Level III NDT technician, qualified in accord with Appendix T for ultrasonic testing, shall review and approve all required ultrasonic examinations.

### 10.5.2 Ultrasonic Acceptance Criteria

Discontinuities that produce a response greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such discontinuities and evaluate them in terms of the acceptance standards given below:

**10.5.2.1** Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

**10.5.2.2** Any relevant indication that intersects the surface of the component or weld shall be rejectable, unless the indication is determined to be caused by a visually (VT) acceptable condition.

**10.5.2.3** Other discontinuities are unacceptable if the indications exceed the reference level and have lengths that exceed the following:

**10.5.2.3.1** 1/4 in. (6.35 mm) for T up to 3/4 in. (19.0 mm), or 1/3 T for T from 3/4 in. to 2 1/4 in. (19.0 mm to 57.2 mm) (T is thickness of the thinner plate of the joint)

**10.5.2.3.2** A group of indications that have an aggregate length greater than T in a weld length of 12T or 6 in., whichever is less, except when the distance between successive indications exceeds 6L, where L is the length of the longest indication in the group.

**10.5.3** Any indication that is believed to be non-relevant shall be regarded as ~~an imperfection~~ a discontinuity unless it is shown by reexamination that no ~~unacceptable imperfections~~ rejectable discontinuities are present. Reexamination shall be performed by the same method or by the use of other nondestructive examination methods and/or by surface conditioning.

<sup>a/</sup> "T" is the thickness of the weld excluding any allowable reinforcement. For a groove butt weld joining two members having different thicknesses at the weld, "T" is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in "T."

## 11.0 PERFORMANCE QUALIFICATION OF WELDERS AND WELDING OPERATORS

### 11.1 Qualification of Welders

Each welder shall pass the mechanical tests prescribed in paragraph 11.6 below for performance qualification, except that welders making a groove weld with shielded metal-arc welding, flux-cored arc welding, gas metal arc welding (except short circuiting), or gas-shielded tungsten arc welding may alternatively be qualified by radiographic ~~or ultrasonic~~ examination as prescribed in paragraph 11.6 below. The welder who welds the welding procedure qualification test plate that results in a qualified WPS shall be performance qualified, but only within the limits of essential variables given in paragraph 11.4 below.

**11.1.1** Performance qualification tests for groove butt, fillet, and buildup welds, including nozzles and other circular attachments to the shell, shall be made using groove butt-welded test plates (see Figs. W.3, Sketch A, W.4, W.14, W.20, Sketch C, and W.20, Sketch D). Groove welds on diameters less than 24" shall require welder performance qualification using pipe (see Fig 4.2). Satisfactory qualification test results on specimens prepared from the groove butt-welded test plates, or alternatively by radiographic examinations, shall qualify a welder to make groove butt welds in thicknesses determined by test plate thickness and fillet welds and weld build-up in all thicknesses, both within the range of essential variables as recorded in the welder's "Record of Welder Performance Qualification Test" (see Fig. W.13).

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

**11.1.2** Performance qualification tests for fillet welds, only, may be made using fillet-welded test plates (see Figs. W6, Sketch A and W.15. Satisfactory qualification test results on specimens prepared from the fillet-welded test plate shall qualify a welder to make fillet welds in all thicknesses within the range of essential variables as recorded in the welder's "Record of Welder Performance Qualification Test" (see Fig. W.13).

**11.2 Qualification of Welding Operators**

Each welding operator who welds on tanks being fabricated, repaired, altered, or converted shall be performance-qualified for each welding process under which the welder does welding with automatic welding equipment, in which both the rate of travel and position of welding head with respect to the work are controlled mechanically, except for minor adjustments for such factors as plate unevenness, out-of-roundness, and lead angle of the welding head. The welding operator who welds the welding procedure qualification test plate that results in a qualified WPS shall be performance-qualified.

**11.2.1** A 3 ft (914 mm) length of weld made by the operator shall be radiographed using the technique of paragraph 10.0 above. To qualify the operator's performance, the radiograph shall comply with the acceptance standards of the same section. The length of weld radiographed may be that of a test plate or of production welding.

**11.2.2** If the weld does not comply with the acceptance standards, second and subsequent 3 ft (914 mm) lengths welded by the operator using the machine-welding procedure shall be radiographed, until the operator demonstrates that he or she is capable of producing welds that comply with the acceptance standards. Production welds so examined shall be unacceptable if they do not comply with the minimum requirements for the tank being fabricated.

**11.2.3** The results of the radiographic examination shall be recorded and retained by the facility. The radiographs may be retained or be discarded.

**11.2.4** Performance qualification tests for fillet welds only may be made using fillet-welded test plates (see Figs. W.6.1 and W15. Satisfactory qualification test results on specimens prepared from the fillet-welded test plate shall qualify a welder to make fillet welds in all thicknesses within the range of essential variables as recorded in the welder's "Record of Welder Performance Qualification Test" (see Fig. W.13).

**11.3 Weldments Involving Combination of Processes**

**11.3.1** Welds requiring a combination of processes may be performed by one or more welding operators or welders, each welding only that portion of the weldment for which he or she is performance-qualified.

~~**11.3.2** Where a combination of processes are used, the welder or welding operator who is to make the root pass shall be tested only by means of a minimum of two root bend specimens instead of the face bend and side bend specimens required in Table W.6.~~

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**11.4 Essential Variables**

When any of the applicable changes in the essential variables as described in paragraph 15.2 below and in Table W.5 are made, the welder shall be requalified.

**Table W.5  
Essential Variables – Performance Qualification**

Essential Variable Changes Requiring Requalification:	F C A W	F W	G M A W	G T A W	S A W	S M A W
<b>Joint Design</b>						
(1) The deletion of the backing in single-welded but joint welds. Double welded groove welds are considered welding with backing.	X		X	X	X	X
<b>Base Metals</b>						
(2) A change in either or both base materials from a nonferrous material shown with one P-number in Appendix M, Table M10, to a nonferrous material shown with another P-number, or to a nonferrous material not shown, except that a change involving only aluminum	X	X	X	X	X	X
(3) A change in base metal thickness beyond the range permitted in Table W.6	X		X	X	X	X
<b>Filler Metals</b>						
(4) A change from one F-number in Tables W.9 and W.11 to any other F-number, or to any other filler metal not listed in tables W.9 and W.11 except qualification under any F-number up to and including F-No. 5, shall qualify a welder for all lower F-Numbers.	X		X	X	X	X
(5) Qualification with and F-No. 2X aluminum filler metal shall qualify to weld with any other F-No. 2X filler metal.			X	X		
(6) A change from one F-number in table W.9 to any other F-Number, or to any other filler metal not listed in Table W.9, except that deposited weld metal using a bare rod not covered by an AWS specification that conforms to an analysis listed in Table W.10, shall be considered to be classified as F-No 6.	X		X	X		
(7) The omission or addition of consumable inserts.	X		X	X	X	X
<b>Positions</b>						
(8) The addition of welding positions other than those already qualified. See paragraph 9.6.	X		X	X	X	X
(9) A change from upward to downward, or from downward to upward, in the progression specified for any pass of a vertical weld.	X		X	X		X
<b>Electrical Characteristics</b>						
(10) A change from spray arc, globular arc or pulsed arc to short-circuiting arc, or vice versa			X			
(11) A change: <ul style="list-style-type: none"> <li>a. From AC to DC, or vice versa.</li> <li>b. In DC welding from electrode negative (straight polarity) to electrode positive (reverse polarity), or vice versa.</li> </ul>				X		
<b>Shielding Gas or Flux</b>						
(12) The omission of gas backing in gas shielded arc welding processes.	X		X	X	X	X
<b>Technique</b>						
(13) A change from one welding process to any other welding process or combination of welding processes.	X		X	X	X	X

## **11.5 Test Joints**

**11.5.1** Information regarding the essential variables in paragraph 11.4 above (base material, filler metal, welding position, etc.) shall be recorded in the facility's "Record of Welder Performance Qualification Test" prepared for each welder qualified (see Fig. W.13.) Other details that are essential variables of the WPS being used shall be followed in making the performance qualification, except as otherwise allowed below. Postweld heat treatment of welder performance test coupons may be omitted. The dimensions of the test plates and the length of the weld shall be sufficient to provide the required test specimens. If the alternative qualification by radiographic ~~or ultrasonic examination~~ is used for groove welds as permitted in paragraph 11.1, the minimum length of weld radiographed or ultrasonically inspected and evaluated in plate shall be 6 in. (153 mm) and shall include a stop-start in each pass along the length of weld.

**11.5.2** The dimensions of the welding groove for the test joint for double-welded groove butt joints and for single-welded groove butt joints with or without backing strip shall be the same as those for any WPS the facility has qualified. The dimensions of the fillet weld shall be as shown in Fig. W.6, Sketch A.

**11.5.3** Carbon and alloy steel. When a welder is to be qualified to weld on carbon or alloy steel, except austenitic stainless steels of P-8, the test plates shall be base metal of the P-number or P-numbers to be joined in production welding, except that carbon steel P-1 base metals may be used for the qualification tests, with the following limitations:

**11.5.3.1** The total alloy content of the base metal, for which carbon steel base metal is substituted, shall not exceed a nominal 6%. The total alloy content of the weld metal used shall not exceed this nominal 6%.

**11.5.3.2** When a welder is to be qualified to weld on alloy steel base metal that has a total alloy content exceeding a nominal 6%, carbon steel plates may be used in the performance qualification tests when using F-41 filler metal of Table W.11. No preheating or postheating is required.

**11.5.3.3** When alloy steel filler metals as permitted in paragraph 11.5.3.1 above are used on carbon steel plate, the test specimens are to be preheated and postheated in accord with the WPS.

**11.5.4** Austenitic stainless steel and nickel-base alloys. When a welder is to be qualified to weld on austenitic stainless steel P-8 metal or nickel alloy P-41 metal, carbon steel plates of P-1 may be used for the performance test.

**11.5.5** When a welder is to be qualified for the use of F-5 filler metal of weld metal analysis A-7 or A-8 to join P-1 or P-8 base metals to themselves or to each other, carbon steel plate may be used for the performance qualification test. A performance qualification test made using A-8 or A-9 (F-5 filler metals) with one or a combination of P-1 or P-8 base metal will qualify for all combinations of these base metals.

## **11.6 Test Specimens**

**11.6.1** The qualification test weld shall be visually inspected in the as-welded condition (no grinding after completing the weld) in accordance with paragraphs 14.5 and 14.10 below, except that reinforcement may be up to 1/8 in. For welder performance qualification by mechanical testing, the type and number of test specimens required, together with the range of thickness of materials for which a welder is qualified by use of a given thickness of test plate, are shown in Table W.6. When alternative qualification by radiographic ~~or ultrasonic~~ examination of groove welds is used as permitted in paragraph 11.1, the range of thickness of materials for which a welder is qualified shall be the same as for mechanical testing in Table W.6.

**11.6.2** Test specimens may be removed from the welded test plates in any order, but in a manner similar to that shown in Figs. W.20, Sketch C, and W20, Sketch D.

**11.6.3** All test specimens shall be prepared, tested and meet the requirements as prescribed in applicable portions of paragraphs 6.0, 7.0, and 9.0 of this appendix. When alternative qualification by radiographic ~~or ultrasonic~~ examination of groove welds is used as permitted in paragraph 11.1, the radiographic ~~or ultrasonic~~ acceptance standards of the applicable portions of paragraph 10.0 above shall be used.

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

---

**11.6.4** The number of test plates (and sets of test specimens) required by Table W6 shall be prepared and tested to provide performance qualification of each welder for the "test positions" that will be used in the fabrication, repair, alteration, or conversion of tank car tanks.

**11.7 Retests**

A welder who fails the performance qualification tests may be retested under the following conditions:

**11.7.1** If one or more of the test specimens prescribed in Table W.6 fails to meet the requirements, or if the qualification failed has been that of the alternative qualification by radiographic examination of paragraph 11.6 above.

**11.7.1.1** When a retest is made without further training or practice, the welder shall make two test welds of each type for each "test position" on which the welder failed, all of which shall meet the requirements.

**11.7.1.2** When the welder has had further training or practice, a complete retest shall be made for each "test position" on which the welder failed to meet the requirements.

**11.7.2** If the performance qualification test failed was by radiographic ~~or ultrasonic examination~~, the retest shall be by the radiographic ~~or ultrasonic~~ examination method, ~~respectively~~.

**11.8 Renewal of Qualification**

Renewal of qualification of welders and welding operators used to fabricate, repair, alter, or convert ~~AAR-approved~~ tank car tanks is required under the following circumstances:

**11.8.1** When the welder or welding operator has not used the specific process for which he or she was qualified by the employer for a period exceeding six months. Renewal of qualifications under this paragraph shall be made in all positions in which welding is to be performed in accordance with Table W.2.

**11.8.2** When there is specific reason to question the welder's ability to make welds that meet this specification. Renewal of qualifications under this subparagraph shall be made in all positions in which welding is to be performed in accordance with Table W.2.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**Table W.6 Performance Qualification Tests Required**

Test on Plate <sup>v</sup>								
Type of Weld	Thickness of Test Plate (T) as Welded, Inches	Visual Screening Inspection	Number of Specimens					
			Bend Tests <sup>j</sup>			T-Joint Break	Macroetch Thickness Test	Qualified, Inches <sup>k</sup>
			Face	Root	Side			
Groove	$T \leq 3/8$	Yes	1	1	---	---	---	$1/8 - 2T^{c/d}$
Groove	$3/8 \leq T < 1/2$	Yes	---	---	2	---	---	$1/8 - 2T^{c/d}$
Groove	1/2 or over	Yes	---	---	2	---	---	$1/8 - \text{unlimited}^{c/d}$
Fillet Option 1 <sup>a</sup>	3/16 - 1/2	Yes	---	---	---	1	1	$1/8 - \text{unlimited}$
Fillet Option 2 <sup>b</sup>	3/8	Yes	---	2	---	---	---	$1/8 - \text{unlimited}$

Test on Pipe											
Type of Weld	Outside Diameter, Inches	Number of Specimens							Outside Diameter Qualified, Inches	Plate or Pipe Wall Thickness Qualified, Inches <sup>k</sup>	
		All Positions Except 5G and 6G only			5G and 6G Positions Only			Macro and Break		Min	Max
		Face Bend	Root Bend	Side Bend	Face Bend	Root Bend	Side Bend				
Groove	$< 0.625$	e	e	---	e	e	---	---	$\geq$ Diameter welded	T/2	$2T^{c/d}$
Groove	$0.625 \text{ to } \leq 2-7/8$	1	1	---	2	2	---	---	$\geq 0.625$	T/2	$2T^{c/d}$
Groove	$> 2-7/8$	1	1	---	2	2	---	---	$\geq$ Diameter welded	T/2	$2T^{c/d}$
Fillet Option 3 <sup>f</sup>	$< 0.625$	---	---	---	---	---	---	1	$\geq$ Diameter welded	1/8	unlimited
Fillet Option 3 <sup>f</sup>	$0.625 \text{ to } \leq 2-7/8$	---	---	---	---	---	---	1	$\geq 0.625$	1/8	Unlimited
Fillet Option 3 <sup>f</sup>	$> 2-7/8$	---	---	---	---	---	---	1	$\geq$ Diameter welded	1/8	Unlimited

<sup>a</sup> See Figure W.XX need to add figure 11.7 (option 1)

<sup>b</sup> See Figure W.XX need to add figure 11.8 (option 2)

<sup>c</sup> Also qualifies for welding fillet welds and applying weld build-up of all sizes on or of material of 1/8 in (3 mm) to unlimited thickness for the positions qualified in Table W.2.

<sup>d</sup> T max for welding operator qualifications.

<sup>e</sup> Radiographic examination required.

<sup>f</sup> See Figure W.XX need to add figure 11.9 (option 3)

<sup>h</sup> T = Thickness of test coupon.

<sup>i</sup> Qualifies groove weld on pipe over 24 in (610 mm) in diameter.

<sup>j</sup> Radiographic examination of welder operator test plate may be made in lieu of the bend test (See Paragraph W.11.6.1)

<sup>k</sup>  $T \geq 1/2$  in (13 mm) thickness qualifies unlimited thickness for plate and pipe.

## **12.0 PROCEDURE QUALIFICATION**

### **12.1 Welding Procedure Specification (WPS)**

**12.1.1** Each company shall prepare Welding Procedure Specifications that are defined as follows:

**12.1.1.1 Welding Procedure Specification (WPS).** A WPS is a written qualified welding procedure prepared to provide direction for making production welds to this specification's requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with this specification. The company shall have and document a clearly defined system to ensure that the welding parameters being used are within the limits of the WPS.

**12.1.1.2 Contents of the WPS.** The completed WPS shall describe all the essential, nonessential, and when notch toughness is required by the tank car specification, the supplementary essential variables for each welding process used in the WPS. These variables are listed for each process in Table W.7, Welding Procedure Specification Data. The WPS shall reference the supporting Procedure Qualification Record(s) (PQR) described in 12.2. The WPS shall include the company's name, date and signature of the responsible official of the company authorizing its use. The company may include any other information in the WPS that may be helpful in making a specification compliant weldment.

**12.1.1.3 Changes to the WPS.** Changes may be made in the nonessential variables of a WPS to suit production requirements without requalification provided such changes are documented. Changes in essential or supplementary essential (when notch toughness is required by the tank car specification) variables require requalification of the WPS (new or additional PQRs to support the change in essential or supplementary essential variables) when those changes are outside the range as permitted by this specification.

**12.1.1.4 Format of the WPS.** The information required to be in the WPS may be in any format, written or tabular, to fit the needs of each company, as long as every essential, nonessential, and, when required, supplementary essential variables as outlined in Table W.7 is included or referenced.

**12.1.1.5 Availability of the WPS.** The WPS used for weldments made to this specification shall be available for reference.

### **12.2 Procedure Qualification Record (PQR)**

**12.2.1** Each company shall be required to prepare Procedure Qualification Record which is defined as follows:

**12.2.1.1 Procedure Qualification Record (PQR).** The PQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

**12.2.1.2 Contents of the PQR.** The completed PQR shall document all essential and when notch toughness is required by the tank car specification, the supplementary essential variables of Table W.8 for each welding process used during the welding of the test coupon. Nonessential or other variables used during the welding of the test coupon may be recorded at the company's option. All variables, if recorded, shall be the actual variables (including ranges) used during the welding of the test coupon. If variables are not monitored during welding, they shall not be recorded. It is not intended that the full range or the extreme of a given range of variables to be used in production be used during qualification unless required due to a specific essential, or when required, supplementary essential variable. The PQR shall include the company's name, date and signature of the responsible official of the company authorizing its use.

**12.2.1.3 Certification of the PQR.** The PQR shall be certified accurate by the company as required by paragraph 9.3. The company may not subcontract the certification function. This certification is intended to be the company's verification that the information in the PQR is a true record of the variables that were used during the welding of the test coupon and that the resulting tensile, bend, or macro (as required) test results are in compliance with this specification.

**12.2.1.4** One or more combinations of welding processes, filler metal and other variables may be used when welding a test coupon. The approximate thickness of weld metal deposited shall be recorded for each set of essential and, when required, supplementary essential variables. Weld metal deposited using each set of variables shall be included in the tension, bend, notch toughness and other mechanical test specimens that are required.

**AAR Manual of Standards and Recommended Practices**  
**Specifications for Tank Cars**

M-1002

APPENDIX W

**12.2.1.5 Changes to the PQR.** Changes to the PQR are not permitted except as described below. Editorial corrections or addenda to the PQR are permitted. An example of an editorial correction is an incorrect base metal or fillet metal number that was assigned. An example of an addendum would be a change resulting from a change to this specification. For example, this specification may assign a new F-Number to a filler metal or adopt a new filler metal under an established F-Number. This may permit, depending on the particular specification requirements, an organization to use other filler metals that fall within that particular F-Number where, prior to the specification revision, the company was limited to the particular electrode classification that was used during qualification. Additional information can be incorporated into a PQR at a later date provided the information is substantiated as having been part of the original condition by lab record or similar data. All changes to a PQR require recertification as required by paragraph 3.0 (including date) by the company.

**12.2.1.6 Format of the PQR.** The information required to be in the PQR may be in any format, written or tabular, to fit the needs of each company, as long as every essential and, when required, supplementary essential variable required by Table W.8 is included. The type of tests, number of tests, and test results shall be listed in the PQR.

**12.2.1.7 Availability of the PQR.** PQR's used to support WPSs shall be available to those authorized to examine them. The PQR need not be available to the welder or welding operator.

**12.2.1.8 Multiple WPSs with One PQR / Multiple PQRs with One WPS.** Several WPSs may be prepared from the data on a single PQR (e.g. a 1G plate PQR may support WPSs for the F, V, H, and OH positions on plate or pipe within all other essential variables). A single WPS may cover several sets of essential variable ranges as long as a supporting PQR exists for each essential and, when required, supplementary essential variable (e.g. a single WPS may cover a thickness range from 1/8 in through 1-1/4 inch if PQR's exist for both the 1/8 in through 3/8 in and 3/8 in through 3/4 in thickness ranges).

**12.2.1.9** To reduce the number of welding procedure qualifications required, M-Numbers/P-Numbers are assigned to base metals dependent on characteristics such as composition, weldability, and mechanical properties, where this can logically be done; and for steel and steel alloys Group Numbers are assigned additionally to M-Numbers/P-Numbers. These Group Numbers classify the metals within M-Numbers/P-Numbers for the purpose of procedure qualification where notch toughness requirements are specified. The assignments do not imply that base metals may be indiscriminately substituted for a base metal which was used in the qualification test without consideration of the compatibility from the standpoint of metallurgical properties, post weld heat treatment, design, mechanical properties and service requirements. Where notch toughness is a consideration, it is presupposed that the base metals meet the specific requirements of M-Number/P-Number and Group Number.

### **12.3 Qualification of Procedure**

**12.3.1 Qualification for Groove Full Penetration Welds.** Groove-welded test coupons shall qualify the thickness ranges of both base metal and deposited weld metal to be used in production. Limits of qualification shall be in accordance with Table W.8. WPS qualification for groove welds shall be made on groove welded test plates using tension and guided bend specimens. Notch toughness tests shall be made when required by paragraph 12.3.5. The WPS shall be qualified for use with groove welds within the range of essential variables listed. Satisfactory qualification test results on specimens prepared from the groove welded test plates shall qualify a WPS for use with both butt and fillet welds, within the range of essential variables.

**12.3.2 Qualification for Partial Penetration Groove Welds.** Partial penetration groove welds shall be qualified in accordance with the requirements of Table W.8 for both base metal and deposited weld metal thickness.

**12.3.2.1** When a Welding Procedure Specification (WPS) has been qualified for a complete joint penetration groove weld, and is applied to the welding of a partial joint penetration groove weld, then a sample of the partial penetration joint shall be prepared and three macroetch cross-sectional test specimens shall be made to demonstrate that the effective weld size of the partial joint is met.

**12.3.3 Qualification for Fillet Welds.** WPS qualification for fillet welds shall be made on groove welded test coupons.

**12.3.3.1** An exception to this is for steels having their mechanical properties enhanced by quenching and tempering, in this instance WPS qualification for fillet welds shall be made using fillet welded test plates (see

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Figures W.6, Sketch B and W.15). Satisfactory qualification test results on specimens prepared from the fillet welded test plates shall qualify a WPS for use with fillet welds, within the range of essential variables.

**12.3.4 Weld Repair and Weld Buildup.** A WPS qualified on groove welds shall be applicable for weld repairs to groove welds and fillet welds (except as excluded in paragraph 12.3.3.1) and for weld buildup under the following provisions:

**12.3.4.1** For fillet weld repairs and weld buildup, there is no limitation on the thickness of base metal or deposited weld metal.

**12.3.4.2** For groove weld repairs, the thickness range for base metal and deposited weld metal shall be in accordance with Table W.8.

~~**12.3.4.3** For weld buildup, there is no limitation on the thickness of base metal and the deposited weld metal shall be in accordance with Table W.8.~~

**12.3.5 Qualification for Pressure Tank Cars.** In addition to the other requirements of this specification, A WPS used in welding Pressure Tank Cars shall be qualified with PQRs that have been Charpy impact tested at or below -30°F (-34°C) to meet the requirements of Table W.1. In addition to the essential variables specified in Table W.8, the supplementary essential variables of Table W.8 shall also be followed. Production tests do not require impact testing, unless otherwise specified. Austenitic stainless steel tanks made in accordance with paragraph 16.9.2 below without post weld heat treatment, using type 304L or 316L filler metals meeting AWS specifications, are exempt from the requirements of this paragraph. WPSs for special commodities shall match the base metal requirements in 49 CFR 179.102.

**12.4 Essential Variables.** When any of the applicable changes in the essential variables, as described in Table W.8 are made in a Welding Procedure Specification (WPS), a new Procedure Qualification Record (PQR) will be required. When notch toughness is required by the tank car specification, the supplementary essential variables of Table W.8 also apply. Nonessential variable changes may be made to a Welding Procedure Specification (WPS) in accordance with paragraph 12.1.1.3.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**12.5 Welding Procedure Specification Data.** The following Matrix indicates the welding data to be included in a WPS for each welding process. A WPS may be presented in any format, written or tabular, provided the data required in this matrix are included (see paragraph W.12.1). The WPS may list variables recorded on the PQR within the full range permitted for a qualification variable and practical limits determined by the company for other than qualification variables.

**Table W.7 Welding Procedure Specification Data**

Welding Procedure Specification Data		F	F		G	G	S	S
		C	C		M	T	A	M
		A	A		A	A		A
		W	W	F	W	W	W	W
		-	-					
		G	S	W				
<b>Joint Design</b>								
1)	Joint type and dimensions.	X	X	X	X	X	X	X
2)	Treatment of backside, method of gouging, preparation.	X	X		X	X	X	X
3)	Backing material, if used.	X	X		X	X	X	X
4)	Total cross section area			X				
5)	Method or equipment used to minimize flash.			X				
6)	End preparation Method.			X				
<b>Base Metal</b>								
1)	M-Number/P-Number and Group Number.	X	X	X	X	X	X	X
2)	Thickness range qualified.	X	X		X	X	X	X
3)	Diameter (tubular only).	X	X		X	X	X	X
4)	Diameter (solid and tubular).			X				
5)	The coating description or type, if present.	X	X	X	X	X	X	X
<b>Filler Metal</b>								
1)	Specification, classification, F- and A-Number, or if not classified, the nominal composition or manufacturer's trade designation.	X	X		X	X	X	X
2)	Weld metal thickness by process and filler metal classification.	X	X		X	X	X	X
3)	Filler metal size or diameter.	X	X		X	X	X	X
4)	Flux-electrode classification.						X	
5)	Penetration enhancing flux.					X		
6)	Supplemental filler metal.	X	X		X	X	X	
7)	Consumable insert and type.					X		
8)	Energized filler metal "hot".					X		
<b>Position</b>								
1)	Welding position(s).	X	X		X	X	X	X
2)	Progression for vertical welding.	X	X		X	X	X	X
<b>Preheat and Interpass</b>								
1)	Preheat Minimum.	X	X	X	X	X	X	X
2)	Interpass temperature maximum (if applicable).	X	X		X	X	X	X
3)	Preheat maintenance.	X	X		X	X	X	X
<b>Heat Treatment</b>								
1)	PWHT temperature and time.	X	X	X	X	X	X	X
2)	Amplitude and number of PWHT cycles following welding cycle.			X				
<b>Shielding Gas</b>								
1)	Torch Shielding gas and flow rate range.	X			X	X		
2)	Root Shielding gas and flow rate range.					X		
3)	Shielding gas composition pressure and purging time.			X				

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

<b>Welding Procedure Specification Data</b>		<b>F</b>	<b>F</b>		<b>G</b>	<b>G</b>		<b>S</b>
		<b>C</b>	<b>C</b>		<b>M</b>	<b>T</b>		<b>M</b>
		<b>A</b>	<b>A</b>		<b>A</b>	<b>A</b>		<b>A</b>
		<b>W</b>	<b>W</b>	<b>F</b>	<b>W</b>	<b>W</b>	<b>S</b>	<b>A</b>
		<b>-</b>	<b>-</b>				<b>A</b>	<b>W</b>
		<b>G</b>	<b>S</b>	<b>W</b>				
<b>Electrical</b>								
1)	Current (or wire feed speed), current type, and polarity.	X	X		X	X	X	X
2)	Voltage range (except for manual welding).	X	X		X	X	X	
3)	Specification, classification, and diameter of tungsten electrode.					X		
4)	Transfer mode.	X	X		X			
5)	Pulsed current mode shall be indicated.	X	X		X	X		X
6)	Flash Time.			X				
7)	Upset Current Time.			X				
<b>Variables</b>								
1)	Welding process and whether manual, semiautomatic, mechanized, or automatic.	X	X		X	X	X	X
2)	For mechanized or automatic, single or multiple electrode and spacing.	X	X		X	X	X	
3)	Single or multiple pass.	X	X		X	X	X	X
4)	Contact tube to work distance.	X	X		X		X	
5)	Cleaning.	X	X		X	X	X	X
6)	Peening.	X	X		X	X	X	X
7)	Stringer or weave bead.	X	X		X	X	X	X
8)	Travel-speed range for mechanized or automatic welding and manual applications requiring heat input calculations.	X	X		X	X	X	
9)	Type and model of equipment.			X				
10)	Upset length and force.			X				
11)	Distance between clamping dies.			X				
12)	Preparation of clamping areas.			X				
13)	Clamping Force.			X				
14)	Forward and/or reverse speeds.			X				
15)	Use of thermal processes.			X				

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**Table W.8  
PQR Essential Variable Changes Requiring WPS Requalification For  
FCAW, FW, GMAW, GTAW, SAW, SMAW**

Essential Variable Changes to PQR Requiring Requalification:	F C A W	F W	G M A W	G T A W	S A W	S M A W
<b>Joint Design</b>						
(1) A change from a fillet to a groove weld.	X		X	X	X	X
(2) A change in the joint configuration.		X				
<b>Base Metals</b>						
(3) A change from one M-Number/P-Number base metal to another M-Number/P-Number base metal or to a combination of M-Number/P-Number base metals. See ASME IX, <i>Welding, Brazing and Fusing Qualifications</i> (P-Numbers), AWS B2.1, <i>Base Metal Grouping for Welding Procedure and Performance Qualification</i> (M-Numbers), and AAR MSRP CIII, Appendix M, Table 10.1 for base metal groupings. Note: An exception to this requirement is a test coupon of base metals M-10C (P-10C) to M-10C (P-10C) shall also qualify for M-1 (P1) to M1 (P1).	X	X	X	X	X	X
(4) A change from one unlisted base metal to a different unlisted base metal or to a listed base metal or vice versa.	X	X	X	X	X	X
(5) A change in base metal thickness beyond the range permitted in Table W.12.	X		X	X	X	X
(6) For single-pass or multiple pass welding in which any pass is greater than 1/2 in (12.7 mm) thick, an increase in base metal thickness beyond 1.1 times that of the qualification test coupon.	X		X	X	X	X
(7) For short-circuiting transfer mode, when the qualification test coupon thickness is less than 1/2 in (12.7 mm), an increase in thickness beyond 1.1 times that of the qualification test coupon.			X			
(8) A change in the specification, type or grade of base metal. When joints are to be made between two different base metals, a procedure qualification shall be made for the applicable combination even if procedure qualifications have been made for each of the two base metals welded to themselves.		X				
(9) A change in the nominal diameter or nominal thickness for tubular cross sections, or in increase in the total cross section area beyond that qualified for nontubular cross sections.		X				
<b>Filler Metals</b>						
(10) A change from one F-Number in Tables W.9 and W.11 to any other F-Number, or to any filler metal not listed in Tables W.9 and W.11.	X		X	X	X	X
(11) For nonferrous filler metal, a change in AWS classification as shown in Table W.11, or to any other filler metal.	X		X	X		
(12) For ferrous metals, a change in the chemical composition of the weld deposit from one A-Number to any other A-Number in Table W.10. Qualification with A-No. 1 shall qualify for A-No. 2 and vice versa. a. In lieu of an A-Number designation, the nominal chemical composition of the weld deposit shall be indicated on the WPS and on the PQR. Designation of nominal chemical composition may also be by reference to the AWS Classification (except for "G" suffix classification), the manufacturer's trade designation, or other established procurement documents.	X		X	X	X	X
(13) The deletion or addition of filler metal.				X		

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Essential Variable Changes to PQR Requiring Requalification:	F C A W	F W	G M A W	G T A W	S A W	S M A W
(14) A change from one of the following filler metal product forms to another: a. Bare (solid or metal cored) b. Flux-cored c. Flux-coated (solid or metal cored) d. Powder	X		X			
(15) Where the alloy content of the weld metal is largely dependent upon the composition of the flux used, any change in any part of the welding procedure which would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the WPS. If there is evidence that the production welds are not being made in accordance with the WPS, the inspector may require that a check be made on the chemical composition of the weld metal. Such a check shall preferably be made on a production weld.	X		X		X	
(16) Where the alloy content of the weld metal is largely dependent upon the composition of the supplemental filler metal, any change in any part of the welding procedure that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the WPS.	X		X		X	
(17) A change in the manufacturer, brand, or product designator (part number) of the filler metal qualified on the Welding Procedure Qualification Record when: a. The electrode has a "G" classification. b. The electrode classification has a required tensile strength lower than that of the base metal. c. The electrode does not have an AWS Classification that defines the chemical limits.	X		X	X	X	X
(18) A change in: a. The indicator for minimum tensile strength (e.g., the 7 in F7A2-EM12K) when the flux/ wire combination is classified by an AWS specification. b. Either the flux trade name or wire trade name when neither the flux nor the wire is classified by AWS specification. c. A change in the flux trade name when the wire is classified by an AWS specification, but the flux is not. d. The flux trade name for A-No. 8 deposits.					X	
(19) The omission or addition of consumable inserts.	X		X	X	X	X
<b>Positions</b>						
(20) A change from upward to downward, or from downward to upward, in the progression specified for any pass of a vertical weld.	X		X	X		X
<b>Preheat</b>						
(21) A decrease of more than 100°F (37.8°C) in the preheat temperature qualified. The minimum temperature for welding shall be specified on the WSP.	X		X	X	X	X
(22) For a preheat temperature of 32°F (0°C), or lower the Welding Procedure Qualification Record test temperature is the minimum.	X		X	X	X	X
(23) A change of more than 10% in the amplitude or number of preheating cycles from that qualified, or if other preheating methods are employed, a change in the preheating temperature of more than 25°F (15°C).		X				
<b>Post Weld Heat Treatment (PWHT)</b>						
(24) The addition or deletion of post weld heat treatment.	X	X	X	X	X	X
(25) A change in the specified post weld heat treatment time and temperature ranges beyond those provided in W16.4 and Table W.16.	X	X	X	X	X	X
(26) A change of more than 10% in the number of PWHT heating current cycles following the welding cycle.		X				

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Essential Variable Changes to PQR Requiring Requalification:	F C A W	F W	G M A W	G T A W	S A W	S M A W
(27) A change in PWHT within a specified temperature and time range if heat treatment is performed separately from the welding operation.		X				
<b>Shielding Gas or Flux</b>						
(28) A change: a. From a single shielding gas to any other single shielding gas. b. From a single shielding gas to a mixture of shielding gasses, and vice versa c. In the specified percentage composition of a shielding gas mixture. d. In the addition or omission of shielding gas.	X		X	X		
(29) A change involving: a. The addition or deletion of gas backing b. The backing gas composition c. The specified flow rate range of the backing gas	X		X	X		
(30) A change in flux: a. Involving either addition or deletion of any material of screen size finer than 200 mesh (79 per 10mm) b. Involving the use of recrushed.					X	
(31) A change in the shielding gas type, gas pressure or purging time.		X				
<b>Electrical Characteristics</b>						
(32) A change from spray arc, globular arc or pulsed art to short-circuiting arc, or vice versa			X			
(33) A change: a. From AC to DC, or vice versa. b. In DC welding from electrode negative (straight polarity) to electrode positive (reverse polarity), or vice versa.	X		X	X		
<b>Technique</b>						
(34) In machine or automatic welding a change from single arc to multiple arc, or vice versa.	X		X	X		
(35) A change from one welding process to any other welding process or combination of welding processes.	X		X	X	X	X
(36) A change in the method or equipment used to minimize internal flash.		X				
(37) A change in the end preparation method.		X				
(38) A change in the flashing time of more than 10%.		X				
(39) A change in the upset current time by more than 10%.		X				
(40) A change in the type of model of the welding equipment.		X				
(41) A change in the upset length or force of more than 10%.		X				
(42) A change in the distance between the clamping dies of more than 10% or a change in the surface preparation of the clamping areas.		X				
(43) A change in the clamping force by more than 10%.		X				
(44) A change in more than 10% of the forward or reverse speed.		X				

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Supplemental Essential Variable Changes to PQR Requiring Requalification: (When Notch Toughness is required by tank car specification)	F C A W	F W	G M A W	G T A W	S A W	S M A W
<b>Joint Design</b>						
(45) A change in groove joint design that results in a. A decrease in the groove angle. b. A decrease in the groove root radius. c. A decrease in the root opening. d. An increase in the root face	✗		✗	✗	X	✗
<b>Base Metals</b>						
(46) Welding Procedure Specifications shall be qualified using one of the following: a. The same base metal (including type or grade) to be used in production welding. b. For ferrous materials, a base metal listed in the same M-Number/P-Number & Group Number as the base metal to be used in production welding. See Table M.10 for tank plate base metals and ASME Section IX for other base metals. c. For nonferrous materials, a base metal listed with the same M-Number/P-Number UNS Number in ASME Section IX, Table QW/QB-422, as the base metal to be used in production welding.	X	X	X	X	X	X
(47) The minimum base metal thickness T qualified: a. Is the thickness of the test coupon T or 5/8 in. (15.9 mm), whichever is less. b. Is 1/2 T when the test coupon T is less than 1/4 in. (6.35mm).	X		X	X	X	X
<b>Filler Metals</b>						
(48) A change in the nominal diameter of the electrode to over 1/4 in. (6.35mm)						X
(49) A change in the AWS specification filler metal classification. <i>(example: For ferrous metals, a change in low hydrogen coating type having the same minimum tensile strength and chemical analysis)</i>	X		X	X		X
(50) A change in filler metal brand name or grade, unless the AWS specification requires charpy impact properties equal to the required values in the relevant post weld heat treated condition.	X		X			
<b>Positions</b>						
(51) A change from: a. Any position to the vertical position, uphill progression. Vertical uphill progression qualifies for all positions. b. Stringer bead to weave bead in the vertical position, uphill progression.	X		X	X		X
<b>Preheat</b>						
(52) An increase of more than 100°F (37.8°C) in the maximum interpass temperature recorded on the Welding Procedure Qualification Record.	X	X	X	X	X	X
<b>Shielding Gas or Flux</b>						
(53) A change in flux brand name or classification/ designation.					X	

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Supplemental Essential Variable Changes to PQR Requiring Requalification: (When Notch Toughness is required by tank car specification)	F C A W	F W	G M A W	G T A W	S A W	S M A W
<b>Electrical Characteristics</b>						
(54) A change in the type of current or polarity.	X		X	X	X	X
(55) An increase in heat input, or an increase in volume of weld metal deposited per unit length of weld. <i>(A change in volume of weld metal means an increase in bead size or a decrease in length of weld bead, per unit length of electrode)</i> <p>a. The increase in heat input shall be determined by (i), (ii), or (iii) for nonwaveform controlled welding, or by (ii) or (iii) for waveform controlled welding.</p> <p>i. Heat input [J/in. (J/mm)]  <math display="block">= \frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed [in./min (mm/min)]}}</math> </p> <p>ii. Heat input using instantaneous energy measurements in joules (J). Heat input [J/in. (J/mm)]  <math display="block">= \frac{\text{Energy (J)}}{\text{Weld bead Length [in. (mm)]}}</math> </p> <p>iii. Heat input using instantaneous power measurements in joules per second (J/s) or Watts (W)  <math display="block">= \frac{\text{Power (J/s or W)} \times \text{arc time (S)}}{\text{Weld bead Length [in. (mm)]}}</math> </p> <p>b. The requirement for measuring heat input or volume of weld metal does not apply when the Welding Procedure Specification is qualified with a grain refining austenitizing heat treatment after welding.</p>	X	X	X	X	X	
<b>Technique</b>						
(56) For the machine or automatic welding process, a change: <p>a. Of more than ±10% in width, frequency, or dwell time of oscillation.</p> <p>b. From a single electrode to multiple electrode, or vice versa.</p>	X		X	X	X	

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**Table W.9 F-Numbers for steel filler metals – grouping of electrodes and welding rods for qualification**

F-No.	AWS Specification No.	AWS Classification No.
1	A-5.1 and 5.5	Exx20, Exx24, Exx27, Exx28
2	A-5.1 and 5.5	Exx12, Exx13, Exx14
3	A-5.1 and 5.5	Exx10, Exx11
4	A-5.1 and 5.5	Exx15, Exx16, Exx18, Exx48
4	A-5.4 other than austenitic	Exx15, Exx16
5	A-5.4 (austenitic)	Exx15, Exx16
6	A-5.17	Fxx-Exx
6	A-5.9	ERxx
6	A-5.18	ERxxS-x
6	A-5.20	ExxT-x
6	A-5.22	ExxxT-x
6	A-5.23	Fxx-Exxx-x, Fxx-ECxxx-x, Fxx-Exxx-xN, Fxx-ECxxx-xN
6	A-5.28	ER-xxx-x, E-xxx-x
6	A-5.29	ExxTx-x

**Table W 10 A-Numbers -- Classification of ferrous weld metal analysis for procedure qualification**

A-No	Type of Weld Deposit	Analysis, Percentage <sup>a</sup>					
		C	Cr	Mo	Ni	Mn	Si
1	Mild Steel	0.15	---	---	---	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40-0.65	---	1.60	1.00
3	Chrome (0.4% to 2%)-Molybdenum	0.15	0.40-2.00	0.40-0.65	---	1.60	1.00
4	Chrome (2% to 6%)-Molybdenum	0.15	2.00-6.00	0.40-1.50	---	1.60	2.00
5	Chrome (6% to 10.5%)-Molybdenum	0.15	6.00-10.50	0.40-1.50	---	1.20	2.00
6	Chrome-Martensitic	0.15	11.00-15.00	0.70	---	2.00	1.00
7	Chrome-Ferritic	0.15	11.00-30.00	1.00	---	1.00	3.00
8	Chromium-Nickel	0.15	14.50-30.00	4.00	7.50-15.00	2.50	1.00
9	Chromium-Nickel	0.30	25.00-30.00	4.00	15.00-37.00	2.50	1.00
10	Nickel to 4%	0.15		0.55	0.80-4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	---	0.25-0.75	0.85	1.25-2.25	1.00
12	Nickel-Chrome-Molybdenum	0.15	1.50	0.25-0.80	1.25-2.80	0.75-2.25	1.00

<sup>a</sup> Single values shown above are maximum

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Table W 11 F-Numbers for nonferrous filler metals – grouping of electrodes and welding rods for qualification

F-No.	AWS Specification No.	AWS Classification No.
		<b>Aluminum and Aluminum-Base Alloys</b>
21	A-5.10	ER 1100
22	A-5.10	ER 5554, ER 5356, ER 5556, ER 5183, ER 5654
23	A-5.10	ER 4043, ER 4047, ER 4145
24	A-5.10	R-SC 51A, R356.0
		<b>Nickel and Nickel-Base Alloys</b>
41	A-5.11	E Ni-1
41	A-5.14	ER Ni-1

**12.6 Test Joints**

**12.6.1** The base material, the filler metal, and the welding procedure shall comply with the applicable Welding Procedure Specification (WPS). Information regarding the essential and, when required, supplementary essential variables in paragraph 12.4 and Table W.8 above shall be recorded in the facility's Procedure Qualification Record (PQR) prepared for each procedure qualified (see Figure W.11) The dimensions of the test plates and length of the welds shall be sufficient to provide the required test specimens.

**12.6.2** The dimension for plates used for fillet welds shall be as noted in Figure W.6, Sketch B.

**12.6.3** When making procedure tests for groove welds, it is recommended that consideration be given to the effect of angular, lateral, and end restraint on the weldment. This applies particularly to material and weld metal of 80,000 psi (552 MPa) tensile strength or higher and heavy sections of both low- and high-tensile-strength material. The addition of restraint during welding may result in cracking that otherwise may not occur.

**12.6.4** Weld grooves for thicknesses less than 5/8 in. (15.9 mm) shall be prepared by thermal processes when such processes are to be employed during fabrication of quenched and tempered materials. This groove preparation shall also include back gouging, back grooving, or removal of unsound weld metal by thermal processes when this procedure is employed during fabrication.

**12.7 Test Specimens**

**12.7.1** For procedure qualifications, the type and number of test specimens required, and the thickness ranges of both base metal and deposited weld metal are shown in Table W.12.

**12.7.2** Test specimens shall be removed in the order shown in Figures W.3, Sketch B; W.6, Sketch B; W.20, Sketch A; and W.20, Sketch B.

**12.7.3** All test specimens shall be prepared, tested and meet the requirements as prescribed in applicable portions of paragraphs 5.0, 6.0, 7.0, 9.0, and 10.2 of this appendix.

**12.7.4** The number of test plates and sets of test specimens required by Table W.12 shall be prepared and tested to provide procedure qualification that will be used in the fabrication, repair, alteration, or conversion of AAR-approved tanks.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

Table W.12 Procedure Qualification – Number and Type of Specimens, Range of Thickness Qualified

1. Groove Welds							
Thickness $T$ of Test Coupon Welded, inches	Range of Thickness $T$ of Base Metal Qualified, in. <sup>a/</sup>		Max Thickness $t$ of Deposited Weld Metal Qualified, in.	Type and Number of Tests Required (Tension and Guided-Bend Tests) <sup>b/</sup>			
	Min. <sup>c/</sup>	Max.		Tension Fig. W.2	Side-Bend Fig. W.4 Sketch C <sup>d/e</sup>	Face-Bend Fig. W.4 Sketch A <sup>e/</sup>	Root-Bend Fig. W.4 Sketch B <sup>e/</sup>
$1/8 \leq T \leq 3/8$	$1/8$ <sup>e/</sup>	$2T$	$2t$	2	(Note i)	2	2
$3/8 < T < 3/4$	$3/16$	$2T$ <sup>h/</sup>	$2t$	2	(Note i)	2	2
$3/4 \leq T$	$3/16$	$2T$ <sup>h/</sup>	$2t$	2	4	---	---

2. Fillet Welds				
Thickness $T$ of Test Coupon Welded, inches	Range of Thickness $T$ of Base Metal Qualified, Inches. <sup>a/</sup>		Type and Number of Tests Required (Tension and Guided-Bend Tests) <sup>b/</sup>	
	Min. <sup>c/</sup>	Max.	Tension Figure W.2	Fillet Weld Tee-Joint Figure W.6, Sketch B <sup>f/</sup>
Fillet (Figure W.6, Sketch B)	unlimited	unlimited	---	5

- a/ All groove welds qualify fillet welds and weld buildup on all base metal thicknesses and all diameters, with no thickness limit for deposited weld metal.
- b/ When impact or corrosion tests are required by the tank specification, they shall be included as a requirement of the procedure qualification and taken at test plate locations as shown in Figures W.9 and W.20, Sketch A and W.2.1.
- c/ Unless restricted by Table W.8, item #48.
- d/ For aluminum alloy 6061, using Figure W.4, Sketch D.
- e/ Longitudinal face-bend and longitudinal root-bend tests (Figure W.3-1) may be used in lieu of side-, face-, and root-bend tests only for testing material combinations differing markedly in physical bending properties between the two base materials or between the weld metal and the base materials.
- f/ Required only for ferritic steels having their mechanical properties enhanced by quenching and tempering.
- g/  $0.5T$  for nonferrous materials, but not less than  $1/8$  inch.
- h/ For gas metal-arc welding, submerged arc welding, and gas tungsten arc welding, the thickness limitations for production welding based on a test plate thickness,  $T$ , shall be as follows:
  1. For single-pass welding, with no backing strip or against a metal or ceramic backing, the maximum thickness welded in production shall not exceed the thickness of the test plate.
  2. If the test plate is welded by a procedure involving one pass from each side, the maximum thickness that may be welded in production shall be  $2T$ , where  $2T$  shall not exceed 2 inches. If sections heavier than 2 inches are to be welded in production, a separate test.
- i/ Four side-bend tests may be substituted for the required face- and root-bend tests, when thickness  $T$  is  $3/8$  in and over.

Notes:

- $T$  = the thickness of the test coupon welded base metal.
- $t$  = the thickness of the weld deposited, excluding reinforcement.

## **12.8 Retests**

**12.8.1** When one or more of the test specimens in Table W.12 fail to meet the requirements, a retest may be made under the following conditions:

**12.8.1.1** When failure of specimens can be attributed to welder performance, an immediate retest may be made.

**12.8.1.2** When failure of the specimens can be attributed to essential variables of the Welding Procedure Specification (WPS), make necessary changes and make a new qualification test.

## **12.9 Renewal of Qualification**

**12.9.1** Once a welding procedure is qualified, it shall continue in effect indefinitely, within the range of its essential variables of the current edition of this specification (see paragraph 9.2.3).

## **13.0 FABRICATION**

### **13.1 Forming**

Forming of plates shall be done by pressure and not by impact. This includes the edges of the plates forming longitudinal joints.

### **13.2 Cutting to Size**

**13.2.1** Ferrous and nonferrous plates, edges of heads, and other parts may be cut to size and shape by mechanical means such as machining, shearing, or grinding or by applicable thermal cutting.

**13.2.2** Oxygen- or arc-cut edges shall be uniform and smooth and shall be free of fins, tears, cracks, loose or thick scale, slag, surface oxides, moisture, grease, and other foreign material that would prevent proper welding. Detrimental oxidation of material that was molten shall also be removed. Discoloration that may remain on oxygen-cut carbon and low-alloy-steel surfaces is not considered detrimental to welding.

### **13.3 Alignment**

**13.3.1** Plates and heads that are being welded shall be fitted, aligned, and retained in position during the welding operation.

**13.3.2** Bars, jacks, clamps, or other appropriate devices, including tack welds, may be used to hold in alignment the edges to be welded. Temporary tack welds shall be removed. Tack welds shall be incorporated during final welding or removed. Temporary and/or tack welds shall be deposited in accordance with a qualified welding procedure. Temporary tack welds shall be removed and the surface restored to original contour. When temporary welds are deposited after unit PWHT, the affected area shall be examined (after removal of the temporary weld) by PT or MT to ensure soundness. Repairs shall be made in accordance with Appendix R.

**13.3.3** The parts to be joined by fillet welds shall be brought into as close contact as practicable. The root opening shall not exceed 3/16 in. (4.8 mm). If the separation is 1/16 in. (1.6 mm) or greater, the leg of the fillet weld shall be increased by the amount of the separation, or the manufacturer shall demonstrate that the required effective weld size has been obtained.

#### **13.3.3.1 Faying Surfaces**

Separation between faying surfaces of lap joints, plug and slot welds, and of butt joints landing on a backing shall not exceed 1/16".

**13.3.4** For ~~butt~~ groove welding of plates of unequal thickness, see Appendix E.

## **13.4 Welding Conditions**

**13.4.1** Welding shall not be done when the ambient temperature is lower than 0 °F (−17.8 °C). At

temperatures between 32 °F (0 °C) and 0 °F (-17.8 °C), the surface of all areas, within 3 in. (76.2 mm) of the point where a weld is to be started, shall be heated to a minimum of 50 °F (10 °C) before welding is started. If the ambient environmental temperature is below 0 °F (-17.8 °C), a heated structure or shelter around the area being welded may maintain the temperature adjacent to the weldment at 0 °F (-17.8 °C) or higher.

**13.4.2** Welding shall not be done when the surfaces of the parts to be welded are wet. Welding shall not be done when rain or snow is falling or during periods of high winds, unless the welder and work are properly shielded.

### **13.5 Out-of-Roundness of Shells**

The shell of a completed tank of circular cross-section shall be circular within ±1% of the inside diameter of the tank at the location of measurement.

### **13.6 Tolerance for Heads**

See Appendix E, paragraph 1.3, for permissible deviation of a head from the specified shape.

### **13.7 Arc Strikes**

Cracks or blemishes (visible marks) caused by arc strikes shall be removed and the surface restored to original contour. When arc strikes are discovered after unit PWHT, the affected area shall be examined (after removal of the arc strike) by PT or MT to ensure soundness. Repairs shall be made in accordance with Appendix R.

### **13.8 Preheat and Interpass Temperature**

Base metal shall be preheated, if required, to a temperature not less than the minimum value listed on the WPS (see Table W.7 for WPS essential variable limitations). The preheat and all subsequent minimum interpass temperatures shall be maintained during the welding operation for a distance at least equal to the thickness of the thickest welded part, but not less than 3 in. in all directions from the point of welding. Minimum interpass temperature requirements shall be considered equal to the preheat requirements, unless otherwise indicated on the WPS. Preheat and interpass temperature shall be checked just prior to initiating the arc for each pass.

## **14.0 WELD JOINTS**

### **14.1 Welder Visual Acuity**

Welders are not subject to the requirements of Appendix T unless also certified to perform nondestructive examination in accordance with Appendix T.

### **14.2 Visual Acuity Requirements**

**14.2.1** Welders must have a documented visual acuity examination administered prior to production welding and at a minimum once every 3 years. Welders shall be examined to ensure that they have natural or corrected near-distance visual acuity in at least one eye such that each individual is capable of reading a Jaeger Number 2 test chart or equivalent at a distance of not less than 12 in.

**14.2.2** Welders examined in accordance with the vision requirements of AWS QC-1, CSA 178.2, or Appendix T meet Appendix W visual acuity requirements for welders.

### **14.3 Cleaning During Welding**

When weld metal is to be deposited over a previously welded surface, all visible slag shall be removed to prevent inclusion of impurities in the weld metal.

### **14.4 Alignment Tolerances**

Alignment of sections at edges that have been ~~butt~~ groove-welded shall be such that the maximum offset is not greater than the applicable amount listed in Table W.13. Joints within tank heads and dome heads shall meet the requirements in Table W.13 for longitudinal joints.

**Table W.13 Alignment tolerances**

Section Thickness, in. (mm)	Direction of Joints in Cylindrical Shells	
	Longitudinal <sup>a/</sup>	Circumferential <sup>a/</sup>
Up to 1/2 (12.7) inclusive	1/4 t	1/4 t
Over 1/2 (12.7) to 3/4 (19.0) inclusive	1/8 in. (3.18 mm)	1/4 t
Over 3/4 (19.0) to 1 1/2 (38.1) inclusive	1/8 in. (3.18 mm)	3/16 in. (4.76 mm)
Over 1 1/2 (38.1) to 2 (50.8) inclusive	1/8 in. (3.18 mm)	1/8 t
Over 2 (50.8)	Lesser of 1/16 t or 3/8 in. (9.52 mm)	Lesser of 1/8 t or 3/4 in. (19.0 mm)

<sup>a/</sup> t is nominal thickness of the thinner section of the joint.

**14.5 Weld Reinforcement (Butt Joint Groove Welds)**

The surface of any weld metal shall be at least flush with the adjoining plate surface and may be built up as reinforcement, which shall not exceed 3/32 in. (2.38 mm) for plates 5/8 in. (15.9 mm) and thinner, nor 1/8 in. (3.18 mm) for thicker plates. The weld bead reinforcement shall have a gradual transition from its maximum allowable crown to the plane of the base metal surface.

**14.5.1** The reinforcement need not be removed, except to the extent that it exceeds the allowable buildup above or does not conform to the requirements of paragraphs 10.2.1 and 14.10 of this appendix.

**14.5.2** For a single-welded butt joint with backing strip, the requirements for reinforcement apply only to the side opposite the backing strip.

**14.5.3** When dissimilar thicknesses are joined, allowable weld reinforcement shall be based on the thickness of the thinner member. The weld reinforcement shall be determined from the higher of the abutting surfaces involved.

**14.6 Fillet Welds**

**14.6.1** Concavity and convexity shall fall within the ranges shown in Table W.14. Weld size of fillet welds shall not be below the specified size by more than 1/32 in., except that fillet welds over 3/16 in. may be 1/16 in. undersize for up to 10% of the length of the weld.

**14.6.2** Weld metal shall be deposited in such a way that adequate penetration into the base metal at the root of the weld is secured.

**14.6.3** Toes of fillet welds shall blend smoothly into base metal.

**Table W.14 Concavity and convexity of fillet welds**

Fillet Leg Size, in. (mm)	Maximum, in. (mm)	
	Concavity	Convexity
Up to 3/16 (4.76) inclusive	1/32 (0.794)	1/32 (0.794)
Over 3/16 (4.76) to 5/16 (7.94) inclusive	1/32 (0.794)	1/16 (1.59)
Over 5/16 (7.94) to 1/2 (12.7) inclusive	1/16 (1.59)	3/32 (2.38)
Over 1/2 (12.7)	3/32 (2.38)	1/8 (3.18)

**14.7 Interrupted Welding**

If the welding is stopped for any reason, care shall be taken in restarting to ensure full penetration to the bottom of the joint and thorough fusion between the weld metal and the base material and to the weld metal previously deposited. All craters shall be filled.

**14.8 Identification of Welds**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**14.8.1** Each welder and welding operator shall stamp his or her identifying number, letter, or symbol, assigned by the manufacturer, adjacent to their welds made in ferrous plates 1/4 in. (6.35 mm) and over in thickness and in nonferrous plates 1/2 in. (12.7 mm) and over in thickness.

**14.8.2** For identifying welds in ferrous plates less than 1/4 in. (6.35 mm) thick and nonferrous plates less than 1/2 in. (12.7 mm) thick, suitable stencil or other surface markings shall be used.

**14.8.3** An acceptable alternative for all plate thicknesses, both ferrous and nonferrous, is for the fabricator to keep a record of welders and welding operators employed on each joint. These records shall be available.

#### **14.9 Repair of Defects**

Defects in welded joints shall be repaired by removing the defect and rewelding. The defect may be removed by mechanical means, by air-carbon arc, or by plasma arc gouging.

#### **14.10 Surface Quality of Welds**

**14.10.1** The surface of the weld shall be free of cracks, overlap, incomplete fusion, and slag. Weld surfaces shall be free from ~~surface~~ porosity. Undercut in tank shell and tank heads shall not be ~~in excess of~~ exceed 0.010 in. and shall not reduce the thickness below the minimum required value ~~in the tank~~. Tank car tank groove welds shall be filled to their specified cross section.

~~14.10.2 Welded joints in draft sills and underframes and other components attached to the tank car tank shall be constructed in such a manner as to limit undercut and porosity to values permitted by AWS D15.1 (current edition). All welds shall be classified as Class 1 unless otherwise specified by the tank manufacturer or car owner. Undercut in tank car tanks shall be limited per paragraph 14.10.1 of this appendix. Unless otherwise specified, undercut on the attachment side or component side of fillet welds is limited to 1/32", or 12-1/2% of the material thickness, whichever is less.~~

**14.10.3** Weld spatter shall not be permitted in areas where it would interfere with the function or corrosion protection of the tank car tank (e.g., interior coating, linings). Weld spatter that resists normal cleaning methods (e.g., de-slagging, blasting, etc.) may be permitted.

#### **14.11 Flux**

**14.11.1** Handling equipment shall be of a design, location, and support that will minimize any tendency toward separation or segregation of flux particle size or density.

**14.11.2** All containers and reservoirs used for flux shall be so designed that they will empty in normal usage with no residue remaining.

**14.11.3** Normal vacuum pickup recycling of unfused flux shall screen all particles of previously fused flux or slag for a screen size not exceeding 10 per 1 in. (4 per 10 mm).

**14.11.4** Recycling of used flux as a separate operation shall remove harmful dusts and foreign materials.

**14.11.5** Where fused flux (slag) is recrushed, net recovered (including crushed) material shall be blended with not less than 25% by weight new flux.

**14.11.6** No reprocessed flux shall contain more than 10% by weight of any material of a screen size finer than 200 mesh (79 per 10 mm).

**14.11.7** Recrushed slag residue from alloying type fluxes shall not be used.

**14.11.8** Flux from damaged packages shall be discarded or shall be dried at a minimum temperature of 500 °F (260 °C) for one hour before use. Flux that has been wet shall not be used.

#### **14.12 Low Hydrogen Electrodes**

When welding procedures involve the use of low hydrogen electrodes, they must be handled in accord with the following requirements:

**14.12.1** Low hydrogen electrodes shall be purchased in hermetically sealed containers. After opening of hermetically sealed containers or removal from baking ovens, electrodes shall be used or stored in an oven held at a temperature of at least 250 °F (121 °C).

**14.12.2** Bake electrodes at the temperature and time shown in Table W.15 if

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

- the seal on a hermetically sealed container is damaged;
- allowable exposure time to atmosphere per Table W.15 is exceeded.

**14.12.3** Electrodes must not be baked more than once.

**14.12.4** Discard electrodes that have been wet.

**Table W.15 Low hydrogen electrodes**

AWS/CSA Specification	Classification Number <sup>a/</sup>	Maximum Atmosphere Exposure Time (hours) <sup>b/</sup>	Dry and Redry	
			Temperature of Electrodes	Minimum Time at Temperature (hours)
AWS A5.1/CSA W48.1 Mild Steel	E70**	4	450 °F–500 °F (232 °C–260 °C)	2
	E70**R	9		
	E70**HZR	9		
	E7018M	9		
AWS A5.5/CSA W48.3 Low Alloy Steel	E70##-X	4	700 °F–800 °F (371 °C–427 °C)	1
	E80##-X	2	700 °F–800 °F	1
	E90##-X	1	700 °F–800 °F	1
	E100##-X	1/2	700 °F–800 °F	1
	E110##-X	1/2	700 °F–800 °F	1

<sup>a/</sup> \*\*=15, 16, 18, 28, 48

##=15, 16, 18

X=A1, B1, B2, etc., and designates composition of the deposited weld metal.

<sup>b/</sup> Alternative atmosphere exposure time may be used as established by testing per AWS D15.1, Railroad Welding Specification.

## **15.0 WELDING DATA**

### **15.1 Welding Variables**

Each welding variable described in this section is applicable as an essential variable when specified in paragraph 11.0 or paragraph 12.0 above.

### **15.2 Essential Variables**

#### **15.2.1 Joints**

**15.2.1.1** The deletion of the backing in single welded butt joint welds. Double welded groove welds are considered welding with backing.

**15.2.1.2** A change in the edge preparation that would make a groove angle smaller, make groove root radius smaller, make root face (land) larger, or decrease the joint root opening.

#### **15.2.2 Base Metals**

**15.2.2.1** A change from a base material having one P number to a material having another P number. Welding procedures must be qualified using approved tank shell material as listed in Appendix M for each material group to be welded. See Appendix M, Table M.10, for tank plate base metals and ASME Section IX for other base metals. ASTM A612 can be used to qualify TC128 Grade B if chemical and mechanical properties of TC128 Grade B are met. Qualifications with AAR TC128 Grade B or ASTM A612 base metals qualify for P-1 materials, but not vice versa. When joints are made between two base materials that have different P numbers, whether nonferrous or ferrous, a welding procedure qualification shall be made for the applicable combination of P numbers, even though procedure qualification tests have been made for each of the materials welded to itself. Welding procedure qualification with a base metal in one P number, or P number plus Group number, qualifies for all other base metals in the same M number grouping (M numbers as defined by AWS D15.1). Qualifications for M number materials do not qualify corresponding P number materials.

**15.2.2.2** A change in either or both base materials from a nonferrous material shown with one P number in Appendix M, Table M.10, to a nonferrous material shown with another P number, or to a nonferrous material not shown, except that a change involving only aluminum and its alloys shown in Table M.10.2 will not require requalification.

**15.2.2.3** A change in base material thickness beyond the range qualified in accord with Table W.6.

**15.2.2.4** A change in base material thickness beyond the range qualified in accord with Table W.12.

**15.2.2.5** Welding procedure qualifications shall be made using one of the following:

- the same base metal (including type and grade) to be used in production welding
- for ferrous materials, a base metal listed in the same P Number Group Number as the base metal to be used in production welding. See Table M.10 for tank plate base metals and ASME Section IX for other base metals.
- for nonferrous materials, a base metal listed with the same P Number UNS Number in ASME IX, Table QW/QB-422, as the base metal to be used in production welding

**15.2.2.6** In all cases, joint tension test specimens of the PQRs must meet the requirements of paragraph 6.3.2 of this appendix.

**15.2.2.7** The minimum thickness qualified is the thickness of the test coupon T or 5/8 in. (15.9 mm), whichever is less. However, where T is less than 1/4 in. (6.35 mm), the minimum thickness qualified is 1/2T.

~~15.2.2.8~~ For single pass or multipass welding in which any pass is greater than 1/2 in. (12.7 mm) thick, an increase in base metal thickness beyond 1.1 times that of the qualification test coupon.

~~15.2.2.9~~ For the short-circuiting transfer mode of the gas metal-arc process, when the qualification test coupon thickness is less than 1/2 in. (12.7 mm), an increase in thickness beyond 1.1 times that of the qualification test coupon.

### ~~15.2.3 Filler Metals~~

~~15.2.3.1~~ A change from one F number in Tables W.9 and W.11 to any other F number, or to any other filler metal not listed in Tables W.9 and W.11, except qualification under any F number up to and including F No. 5, shall qualify a welder for all lower F numbers.

~~15.2.3.2~~ For the ferrous metals in Table W.10, a change in the chemical composition of the weld deposit from one A number to any other A number in Table W.10. Qualification with A No. 1 shall qualify for A No. 2 and vice versa. In lieu of an A number designation, the nominal chemical composition of the weld deposit shall be indicated on the PQR and WPS. Designation of nominal chemical composition may also be by reference to the AWS classification (where such exists), the manufacturer's trade designation, or other established procurement documents.

~~15.2.3.3~~ A change from a nonferrous filler metal listed with one AWS classification number in Table W.11 to a filler metal listed with another classification number, or to any other filler metal.

~~15.2.3.4~~ The deletion or addition of filler metal.

~~15.2.3.5~~ A change from one of the following filler metal product forms to another:

- ~~• flux cored~~
- ~~• bare (solid) or metal cored~~
- ~~• powder~~

~~15.2.3.6~~ The addition or deletion or change of more than 10% in volume of supplemental filler metal as qualified.

~~15.2.3.7~~ In submerged arc welding where the alloy content of the weld metal is largely dependent upon the composition of the flux used, any change in any part of the welding procedure that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the applicable WPS. If there is evidence that production welds are not being made in accord with the applicable WPS, the inspector may require that a check be made on the chemical composition of the weld metal. The check preferably shall be made on a production weld.

~~15.2.3.8~~ Where the alloy content of the weld metal is largely dependent upon the composition of the supplemental powdered filler metal, any change in any part of the welding procedure that would result in the important alloying elements in the weld metal being outside of the specification range of chemistry given in the procedure specification.

~~15.2.3.9~~ Qualification with an F No. 2X aluminum filler metal shall qualify to weld with any other F No. 2X filler metal.

~~15.2.3.10~~ If filler metal does not have an AWS classification that defines chemical limits, a change in weld wire brand name or grade.

~~15.2.3.11~~ A change from one F number in Table W.9 to any other F number, or to any other filler metal not listed in Table W.9, except that deposited weld metal using a bare rod not covered by an AWS specification that conforms to an analysis listed in Table W.10, shall be considered to be classified as F No. 6.

~~15.2.3.12~~ A change in the nominal diameter of the electrode to over 1/4 in. (6.35 mm).

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

~~15.2.3.13~~ A change in the AWS specification filler metal classification, or to a weld metal or filler metal composition not covered by these specifications.

~~**Exception:** For carbon steel, low alloy steel, and stainless steel, a change in low hydrogen coating type having the same minimum tensile strength and chemical analysis.~~

~~15.2.3.14~~ A change in FCAW filler metal brand name or grade, unless the AWS specification requires Charpy properties equal to the required values in the relevant postweld heat treated condition.

~~15.2.3.15~~ A change in

- ~~• the indicator for minimum tensile strength (e.g., the “7” in F7A2 EM12K) when the flux/wire combination is classified by AWS specifications.~~
- ~~• either the flux trade name or wire trade name when neither the flux nor the wire is classified by AWS specifications.~~
- ~~• the flux trade name for A No. 8 deposits.~~

~~15.2.3.16~~ When a filler metal with a minimum required tensile strength less than the base metal is used, the filler metal brand and grade must be essential variables.

~~15.2.3.17~~ The omission or addition of consumable inserts.

#### ~~15.2.4~~ **Positions**

~~15.2.4.1~~ The addition of welding positions other than those already qualified. See paragraph 9.6 above.

~~15.2.4.2~~ A change from any position to the vertical position, uphill progression. Vertical uphill progression qualifies for all positions. In uphill progression, a change from stringer bead to weave bead.

~~15.2.4.3~~ A change from uphill to downhill, or from downhill to uphill, in the progression specified for any pass of a vertical weld.

#### ~~15.2.5~~ **Preheat**

~~15.2.5.1~~ A decrease of 100 °F (37.8 °C) or more in the minimum specified preheating temperature of the qualification test. The minimum temperature for welding shall be specified in the WPS. See paragraph 13.4.1 in this appendix.

~~15.2.5.2~~ An increase of more than 100 °F (37.8 °C) in the maximum interpass temperature recorded on the PQR.

~~15.2.5.3~~ For a preheat temperature of 32 °F (0 °C) or lower, the PQR test temperature is the minimum.

#### ~~15.2.6~~ **Postweld Heat Treatment**

A separate procedure qualification is required for each of the following:

- ~~• No PWHT (**Note:** Alternate PWHT times and temperatures listed in Table W.16 may be used without welding procedure requalification.)~~
- ~~• PWHT within a specified temperature range~~

#### ~~15.2.7~~ **Electrical Characteristics**

~~15.2.7.1~~ A change from spray arc, globular arc, or pulsed arc to short circuiting arc, or vice versa.

~~15.2.7.2~~ A change from AC to DC, or vice versa. In DC welding, a change from direct current electrode negative (straight polarity) to direct current electrode positive (reverse polarity), or vice versa.

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

~~15.2.7.3~~ A change in the type of current or polarity, an increase in heat input, or an increase in volume of weld metal deposited per unit length of weld, over that qualified. The increase may be measured by either of the following:

~~15.2.7.3.1~~ Heat input

Conventional Units	SI Units
$\text{Heat input (J/in.)} = \frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed (in./min)}}$	$\text{Heat input (J/cm)} = \frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed (cm/min)}}$

~~15.2.7.3.2~~ A change in volume of weld metal means an increase in bead size, or a decrease in length of weld bead, per unit length of electrode.

The requirement for measuring the heat input or volume of deposited weld metal does not apply when the procedure specification is qualified with a grain refining austenitizing heat treatment after welding.

**~~15.2.8 Shielding Gas or Flux~~**

~~15.2.8.1~~ A change from a single gas to any other single gas or to a mixture of gases, or a change in specified percentage composition of gas mixture.

~~15.2.8.2~~ In gas shielded arc welding processes, the omission of gas backing.

~~15.2.8.3~~ A change in flux brand name or designation.

~~15.2.8.4~~ A change in flux involving either addition or deletion of any material of screen size finer than 200 mesh (79 per 10 mm).

~~15.2.8.5~~ A change in flux involving the use of recrushed flux.

**~~15.2.9 Technique~~**

~~15.2.9.1~~ A change in width, frequency, or dwell time of oscillation for machine or automatic welding only.

~~15.2.9.2~~ In machine welding, a change from single arc to multiple arc, or vice versa.

~~15.2.9.3~~ A change from single electrode to multiple electrode, or vice versa, for machine or automatic welding only.

~~15.2.9.4~~ A change from one welding process to any other welding process or combination of welding processes.

## **16.0 POSTWELD HEAT TREATMENT**

### **16.1 General**

**16.1.1** Postweld heat treatment, when required, shall be done before the final hydrostatic test, after any repairs to welding, and after all attachments to be welded to the tank shell or heads have been welded in place.

**16.1.2** Minimum temperatures required by this section shall be temperatures of plate material of shell and heads of the tank.

**16.1.3** Thickness referred to as controlling the heating rate and holding time shall be the metal thickness of the thickest shell or head plate in the tank.

**16.1.4** Tank shell and head material shall determine postweld heat treatment requirements. See Appendix R, paragraph 24.0.

### **16.2 Procedures for Postweld Heat Treatment**

**16.2.1** The tank shall preferably be postweld heat treated as a unit in an enclosed furnace.

**16.2.2** A tank may be postweld heat treated in more than one heat in a furnace, provided the overlap of the heated sections of the tank is at least 5 ft (1520 mm).

Any portion of the tank outside the furnace shall be shielded so that the temperature gradient is not harmful to the tank.

### **16.3 Requirements for Postweld Heat Treatment**

**16.3.1** The furnace shall be designed to prevent direct flame impingement on the tank being heated.

**16.3.2** During the heating, holding, and cooling periods, the furnace atmosphere shall be controlled to avoid excessive oxidation of the tank surface.

**16.3.3** The temperature of the furnace shall not exceed 800 °F (427 °C) at the time the tank or part is placed in it.

**16.3.4** Above 800 °F (427 °C), the rate of heating shall be not more than 400 °F per hour divided by the tank thickness in inches, but in no case more than 400 °F (204 °C) per hour.

**16.3.5** During the heating period, there shall be no greater variation in temperature throughout the portion of the tank being heated than 250 °F (139 °C) within any 15 ft (4570 mm) interval of length.

**16.3.6** During the holding period, there shall be no greater difference than 150 °F (83.3 °C) throughout the portion of the tank being heated, except when a smaller difference is specified for a specific material.

**16.3.7** Above 800 °F (427 °C), cooling shall be done in a closed furnace or cooling chamber, or in still air, at a rate not greater than 500 °F per hour divided by the tank thickness in inches, but in no case more than 500 °F (260 °C) per hour. Below 800 °F (427 °C), the tank may be cooled in still air or in a cooling chamber.

**16.3.8** Holding temperatures and/or holding times in excess of the minimum values specified in this section for specific types of materials may be used, except when otherwise specified, for a specific material.

### **16.4 Carbon Steel Tanks (Material Group 1)**

Unless otherwise provided in the specifications for a tank, all tanks fabricated from

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

materials in Appendix M, Table M.10.1, shall be postweld heat treated at a minimum temperature of 1100 °F (593 °C) for a minimum holding time of one hour per 1 in. (25.4 mm) of tank thickness, with a minimum of one hour for thickness less than 1 in. (25.4 mm). The maximum temperature during postweld heat treatment shall not exceed 1250 °F (677 °C).

**16.4.1** When it is impractical to postweld heat treat at the minimum temperature of 1100 °F (593 °C), any of the lower temperatures and corresponding longer times shown in Table W.16 may be used. Requalification of the welding procedure specification is not required.

**Table W.16 Permissible postweld heat treatment time-temperature combinations**

Metal Temperature <sup>a/</sup>		Holding Time Hours per 1 in. (25.4 mm) of Thickness <sup>b/</sup>
°F	°C	
1050	566	2
1000	538	3
950	510	5
900	482	10

<sup>a/</sup> For intermediate temperature, the holding time shall be determined by straight-line interpolation.

<sup>b/</sup> The holding times shown are minimum for thickness less than 1 in. (25.4 mm).

**16.4.2** Nickel-clad tanks shall not be heated to a temperature exceeding 1200° F (649 °C) and shall be heated in an atmosphere essentially free of sulfur.

**16.4.3** Type 304L- or 316L-clad tanks shall not be heated to a temperature exceeding 1050 °F (566 °C).

**16.5 Manganese-Molybdenum Steel Tanks (Material Group 1)**

Unless otherwise provided in the specifications for a tank, all tanks fabricated from materials in Appendix M, Table M.10.6, shall be postweld heat treated as required for carbon steel tanks in paragraph 16.4 above.

**16.6 Manganese-Silicon Steel Tanks (Material Group 1)**

**16.6.1** Unless otherwise provided in the specifications for a tank, and except as required in paragraph 16.6.2 below, all tanks fabricated from materials in Appendix M, Table M.10.7, shall be postweld heat treated as required for carbon steel tanks in paragraph 16.4 above.

**16.6.2** When the base material has been heat treated by tempering, the maximum postweld heat treatment shall be at least 50 °F (27.8 °C) below the tempering temperature.

**16.7 Nonferrous Metal Tanks (Material Groups 2, 4)**

**16.7.1** Tanks fabricated from aluminum and its alloys shall not be postweld heat treated.

**16.7.2** Tanks fabricated from nickel are not required to be postweld heat treated. Nickel tanks, if heat treated, shall not be heated to a temperature exceeding 1200 °F (640 °C) and shall be heated in an atmosphere essentially free of sulfur.

**16.8 Nickel Alloy Steel Tanks (Material Group 7)**

**16.8.1** Unless otherwise provided in the specifications for a tank, all tanks fabricated from materials in Appendix M, Table M.10.5, shall be postweld heat treated in the temperature range 1025 °F to 1085 °F (552 °C to 585 °C) for a period of two hours, plus one hour for each 1 in. (25.4 mm) of tank thickness over 1 in. (25.4 mm).

**16.8.2** In lieu of the requirements of paragraph 16.3.7 above, the cooling rate from 1025 °F

(552 °C) to 600 °F (316 °C) shall be a minimum of 300 °F (167 °C) per hour in air or water.

### **16.9 High Alloy Steel Tanks (Material Group 3)**

Unless otherwise provided in the tank specifications, the following postweld heat treatment requirements apply to tanks fabricated from materials in Appendix M, Table M.10.3:

**16.9.1 Types 304 and 316.** Tanks fabricated from these materials shall be postweld heat treated (solution annealed) and shall be capable of meeting the corrosion rates listed in Appendix M, paragraph 3.3.2, and the mechanical properties listed in Table M.10.3. Solution annealing shall consist of heating the material to a temperature of 1900 °F (1038 °C) minimum, followed by water quenching or rapid cooling by other means.

**16.9.2 Types 304L and Type 316L.** Tanks fabricated from these materials are not required to be postweld heat treated.

## **~~17.0 QUALITY ASSURANCE~~**

### **~~17.1 Quality Control Program~~**

~~See the AAR Manual of Standards and Recommended Practices, Section J, Specification M-1003, for quality assurance requirements.~~

## **18.0 INSPECTION REQUIREMENTS**

### **18.1 General**

**18.1.1** Unless otherwise provided in a tank specification, the requirements of this section shall apply. For the purposes of this section, "inspection" refers to either radiography (RT) or ultrasonic testing (UT).

**18.1.2** All rewelded or repaired areas shall be re-examined by the original nondestructive test method that discovered the defect.

~~**18.1.3** All radiographic examinations shall be made using the technique and acceptance standards of paragraph 10.2 above.~~

~~All ultrasonic examinations shall be made using the technique and acceptance standards of paragraph 10.5 above, provided the process is automated. Automated scanning is the relative displacement of the ultrasonic beam and the material being tested by other than manual means. Manual ultrasonic inspection methods are prohibited for initial inspection of tanks constructed in groups per paragraph 18.3. Other than welds in paragraph 18.2.3, all ultrasonic examinations shall be performed using automated or semi-automated techniques and using the acceptance standards of paragraph 10.5 above.~~

### **18.1.4**

### **18.2 Welded Joints to be Inspected (Radiograph or Ultrasonic)**

**18.2.1** The entire length of the following ~~double-welded~~ complete penetration butt joints shall be inspected:

**18.2.1.1** All longitudinal and circumferential joints of a tank, except circumferential joints in a multi-unit tank car tank need not be radiographed or ultrasonically inspected.

**18.2.1.2** The joint between the shell and certain types of fittings used to provide a reinforced opening. See Appendix E, Fig. E.20.2.

**18.2.2** The entire length of a single-welded complete penetration butt joint with backup shall be inspected when it is used, in combination with less than a full fillet weld, to attach the interior heads of compartment tanks. See Appendix E.

**18.2.3** All complete penetration groove welds, including nozzle-to-tank groove welds, welded directly to the tank shell or head shall require radiography or automated, semi-automated or

manual ultrasonic inspection as follows:

**18.2.3.1 Pressure Tanks** – 100% of the weld length shall be inspected

**18.2.3.2 Nonpressure Tanks** - A 6 in. minimum continuous length of each weld shall be inspected (for welds less than 6 inches long, 100% of the weld length shall be inspected). If the inspected length of weld does not meet the specified acceptance criteria of paragraph 10.0 (for the NDT method used), then 100% of the weld length shall be examined using the same NDT method. For tanks constructed in groups per paragraph 18.3 below, if the first three tanks are acceptable, then every 1 in 5 tanks, chosen at random, shall be inspected per the above. If any subsequent tank has more than 2 rejectable discontinuities, then three additional tanks shall be inspected and accepted prior to reverting back to every 1 in 5 tanks. The two rejectable discontinuities must be separated by no less than 10 times the component thickness to qualify for this exemption. Note: Each weld type shall be treated independently, i.e. the long seam of a nozzle shall be inspected independent of the nozzle-to-shell weld.

#### **18.2.4 Exceptions**

The following ~~double-welded~~ complete penetration groove welds do not require radiographic inspection or ultrasonic inspection:

- Nozzle-to-flange welds
- Nozzle-to-reinforcing pad welds

### **18.3 Inspection of Nonpressure Tanks Constructed in Groups**

**18.3.1** When a series of carbon steel or high alloy steel tanks made in accord with DOT 179.200 or DOT 179.220, using the same material specifications grouping and welding procedures, are being welded in succession, all ~~double-welded~~ complete penetration butt joints in each weld joint category must be inspected in accord with paragraph 18.2.1 above, except as follows:

#### **18.3.2 Weld Joint Category**

**18.3.2.1** The ~~double-welded~~ complete penetration butt joints in the tanks may be categorized with respect to WPS, ~~welder or welding operator, and welding machine~~. The certified facility shall document each category definition and the limitations of each category. Each category shall be limited to the scope defined in the certified facility's documentation. Accordingly, the ~~double-welded~~ complete penetration butt joints in a tank may be placed in one or more categories.

**18.3.2.2** Welds in each category shall be treated independently of welds in other categories, and acceptance or rejection and requirements for complete radiography of welds in one category shall have no effect on welds in other categories.

**18.3.3** If, in the first 3 tanks in the initial series of 20 tanks, there are no more than two ~~unacceptable defects~~ rejectable discontinuities in any circumferential joint, nor more than one ~~unacceptable defect~~ rejectable discontinuity in any 15 ft (4570 mm) longitudinal joint, then for the next 17 tanks, only the intersections of the longitudinal and circumferential ~~double-welded~~ complete penetration butt joints need be inspected. The two ~~unacceptable defects~~ rejectable discontinuities in a circumferential joint must be separated by no less than 10 times the shell thickness of the thinner member to qualify for this exception.

#### **18.3.4 Inspection of Intersections**

**18.3.4.1** An inspection of an intersection shall include at least 6 in. (152 mm) of the longitudinal joint and at least 2 in. (50.8 mm) of the circumferential joint on each side of the intersection.

**18.3.4.2** When a weld joint contains a rejectable discontinuity ~~an unacceptable defect~~, inspection

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

---

of a 6 in. (152 mm) length of the weld joint in question, on each side of the defective weld area, is required.

**18.3.4.3** If the welds adjacent to the defective welds are acceptable, then the tank welding in question shall be deemed acceptable, and the defective welds shall be repaired and inspected until they are acceptable.

**18.3.4.4** If the welding of the adjacent areas does not comply with the acceptance standards, then all ~~double-welded~~ complete penetration butt joints in that weld category in the tank, as well as in the two successive tanks, shall be inspected throughout their entire length. These three tanks shall be considered the first of an initial series with respect to that category only, and the inspection examination procedure shall revert to that specified in paragraph 18.3.1 above.

**18.3.5 Succeeding tanks**

**18.3.5.1** In each successive series of 20 tanks, only the intersections of the longitudinal and circumferential ~~double-welded~~ complete penetration butt joints need be inspected, except that one tank, selected at random by the inspector, shall be inspected in accordance with paragraph 18.2.1 above.

**18.3.5.2** If there are no more than two ~~unacceptable defects~~ rejectable discontinuities in any inspected circumferential joint, nor more than one unacceptable defect in any 15 ft (4570 mm) length of inspected longitudinal joint, then for the remaining tanks in the series, only the intersections of the longitudinal and circumferential ~~double-welded~~ complete penetration butt joints need be inspected. The two ~~unacceptable defects~~ rejectable discontinuities in a circumferential joint must be separated by no less than 10 times the tank shell thickness to qualify for this exception.

**18.3.5.3** If ~~defects~~ rejectable discontinuities exceed those in paragraph 18.3.5.2 above, then the tank shall be treated as the first in an initial series of 20 tanks, and the inspection procedure shall revert to that specified in paragraph 18.3.1 above.

**Figures to add to Appendix W**

Figure xx – Test Positions for Groove Welds on Pipe

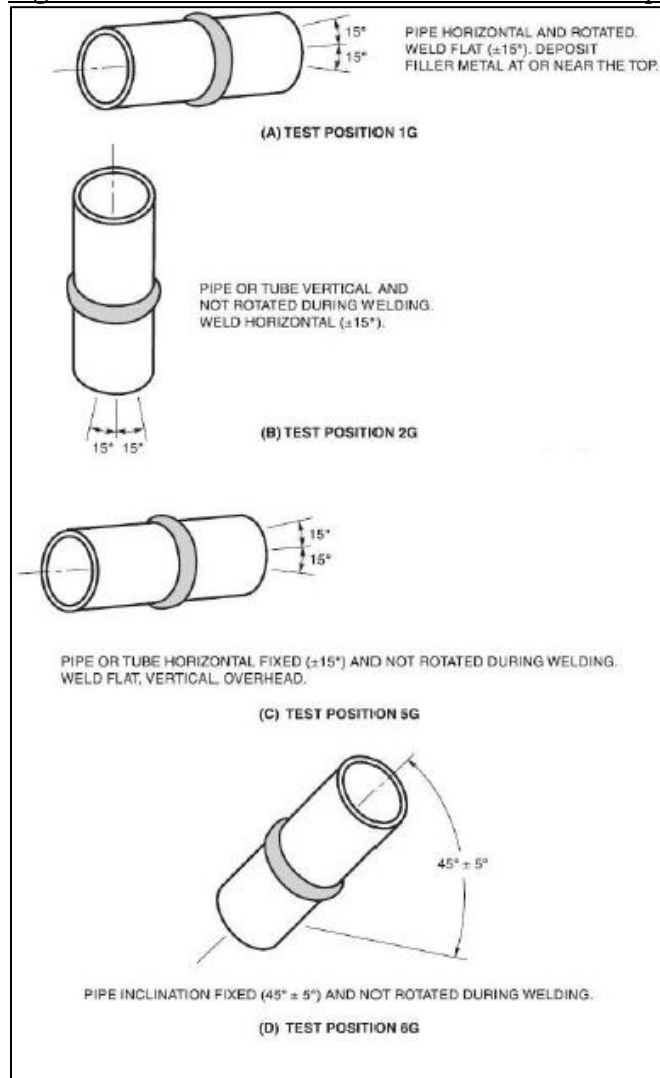






Figure xx – Groove Weld Root-Bend Test Plate Welder and  
Welding Operator Qualification – Option 2

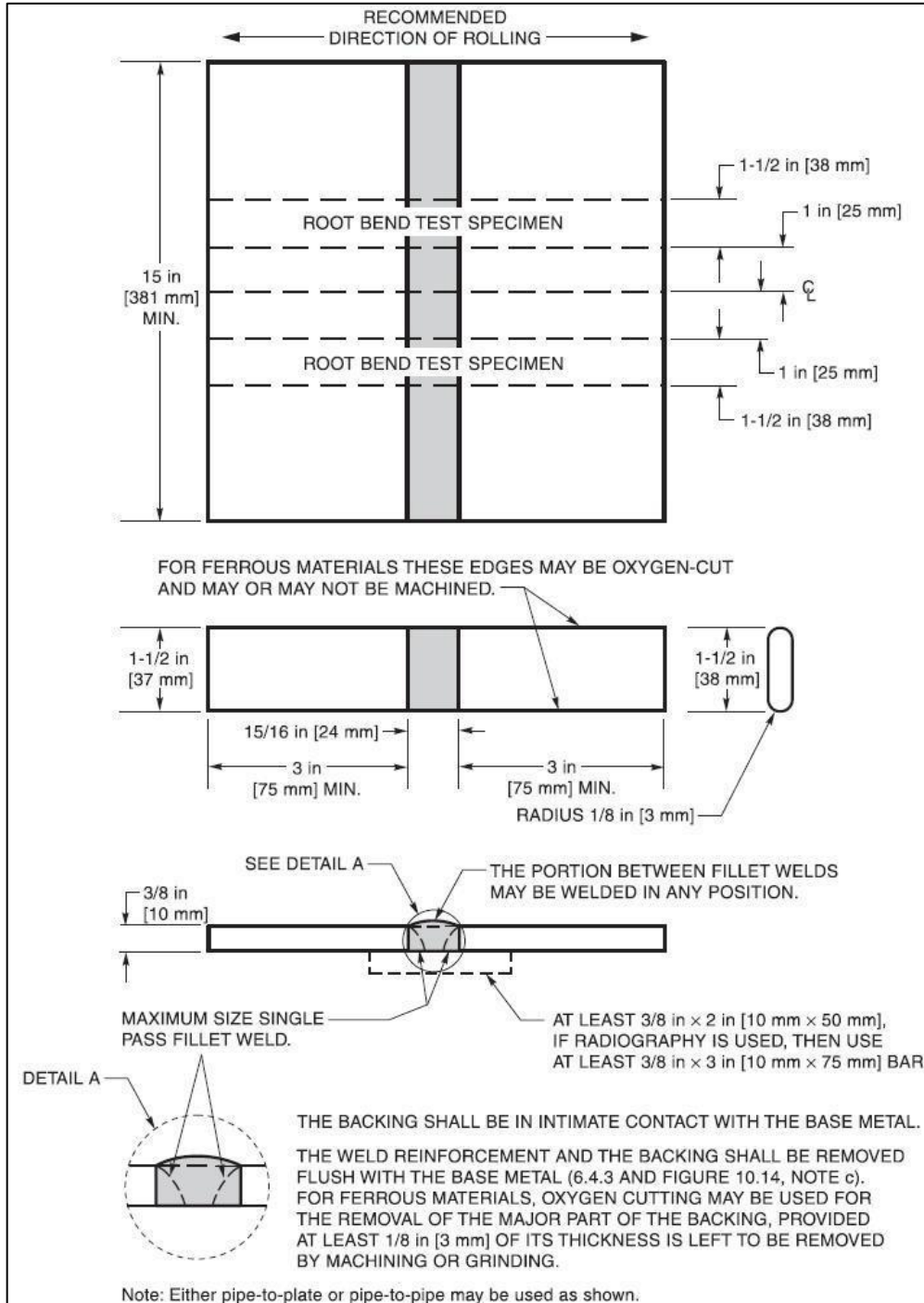


Figure xx – Fillet Weld on Pipe – Welder and  
Welding Operator Qualification – Option 3

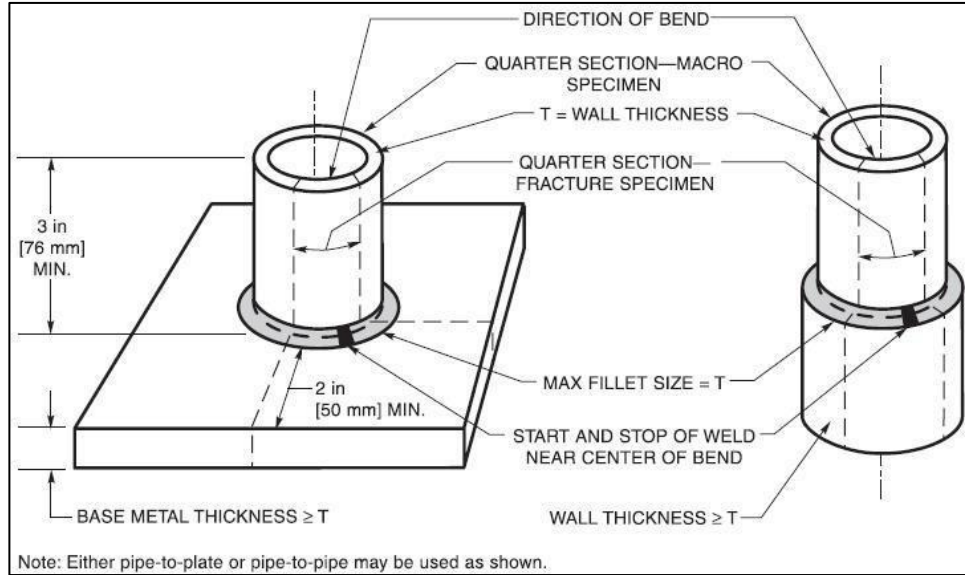
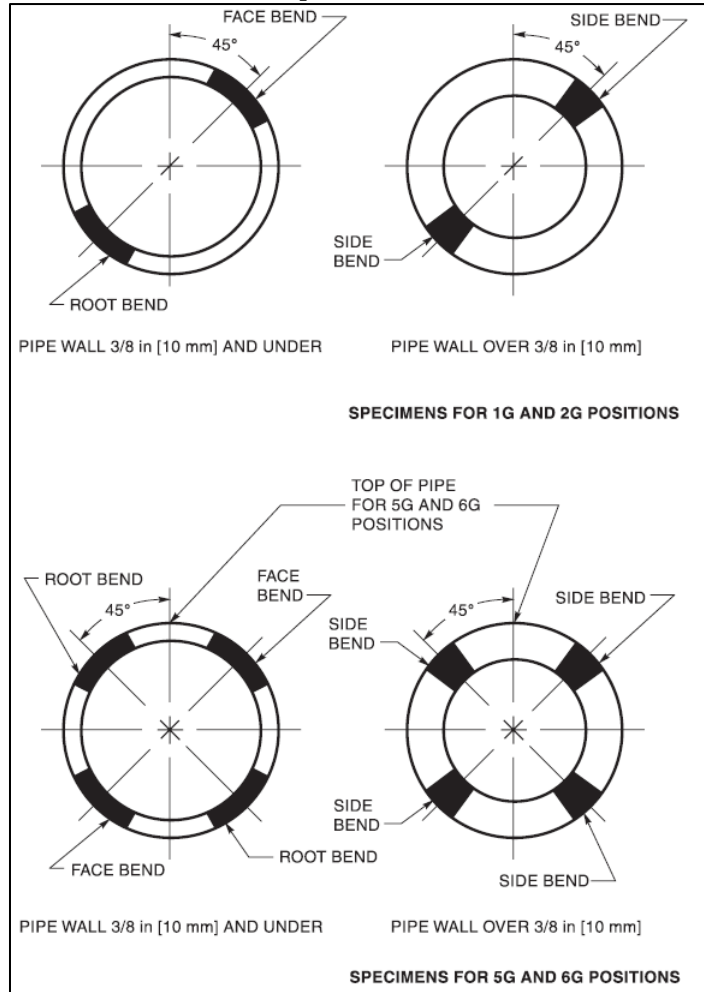


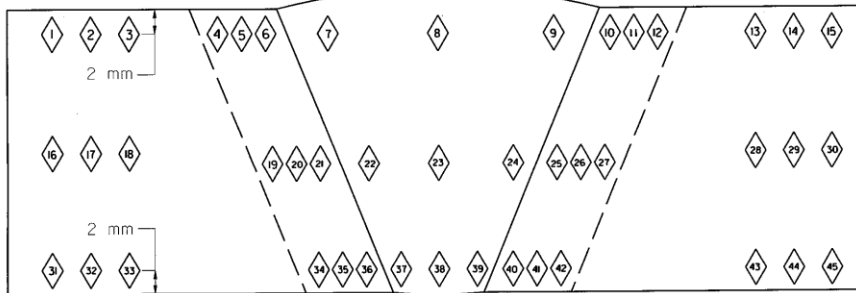
Figure xx – Location of Test Specimens on  
Welded Test Pipe – Welder Qualification



**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

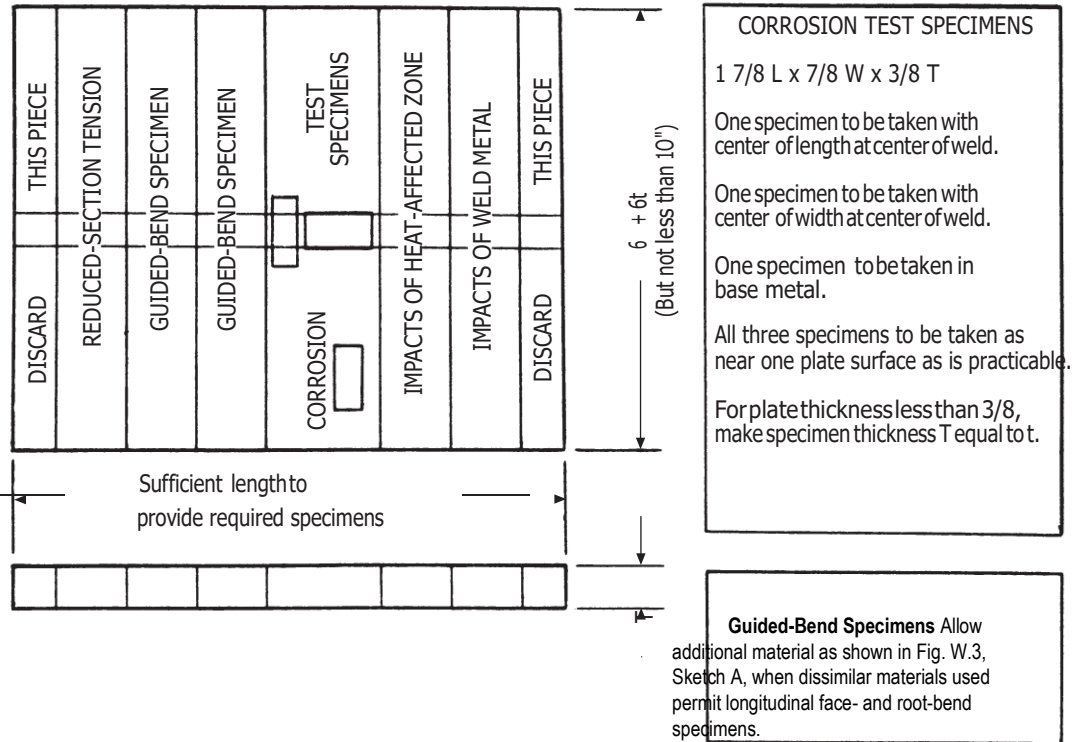
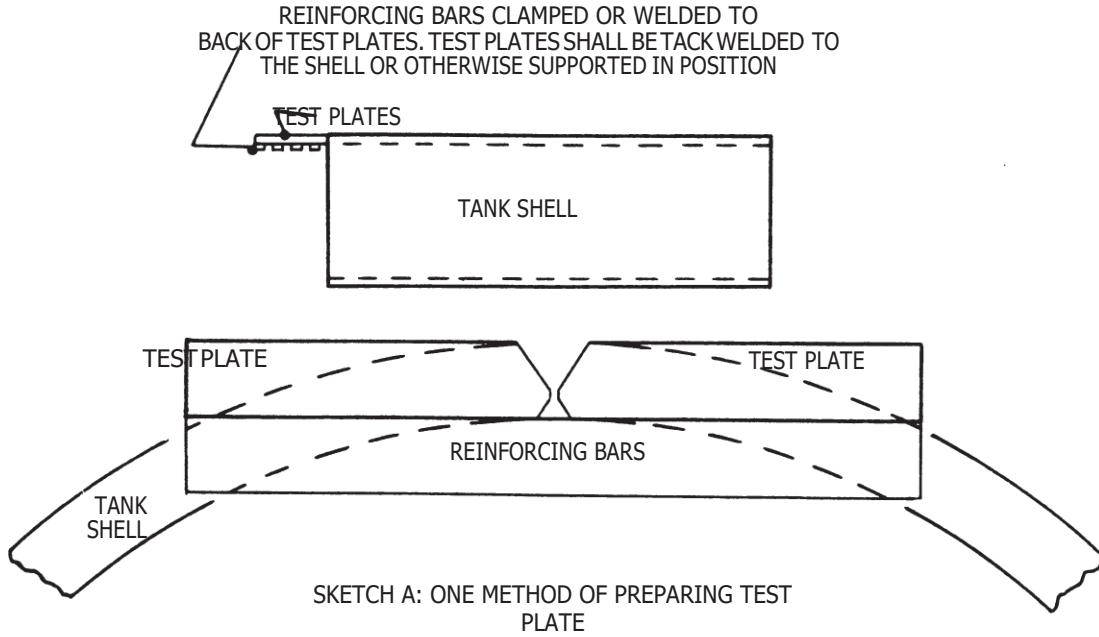
APPENDIX W



**FIGURE W22 MICROHARDNESS SURVEY**

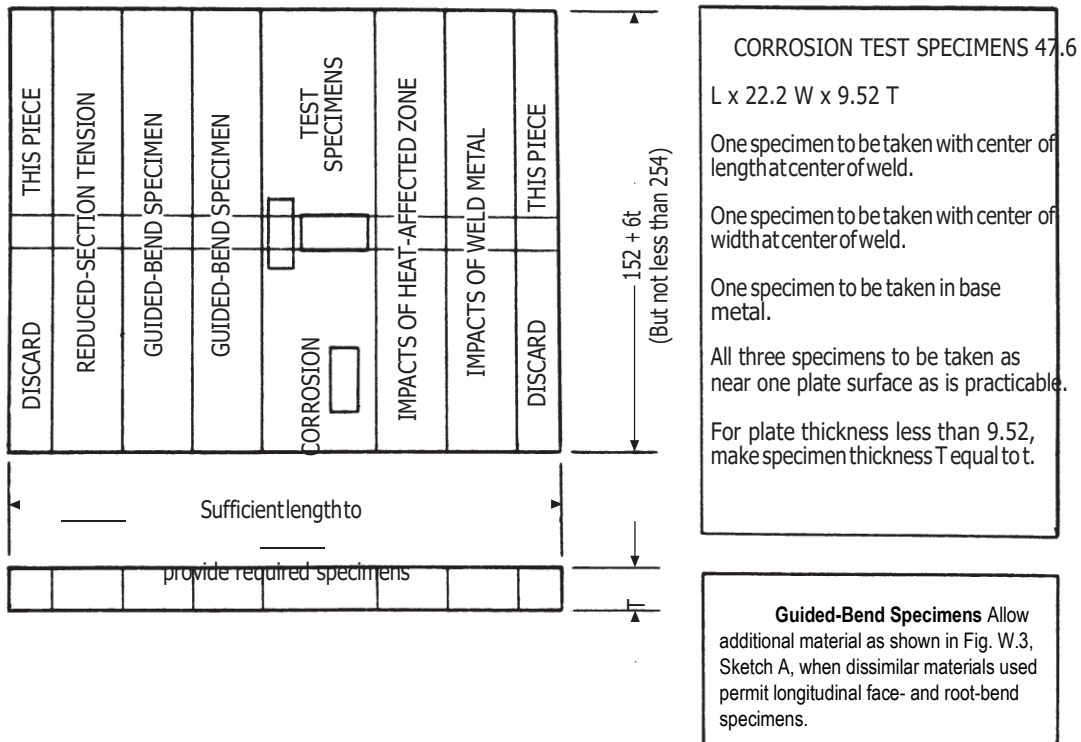
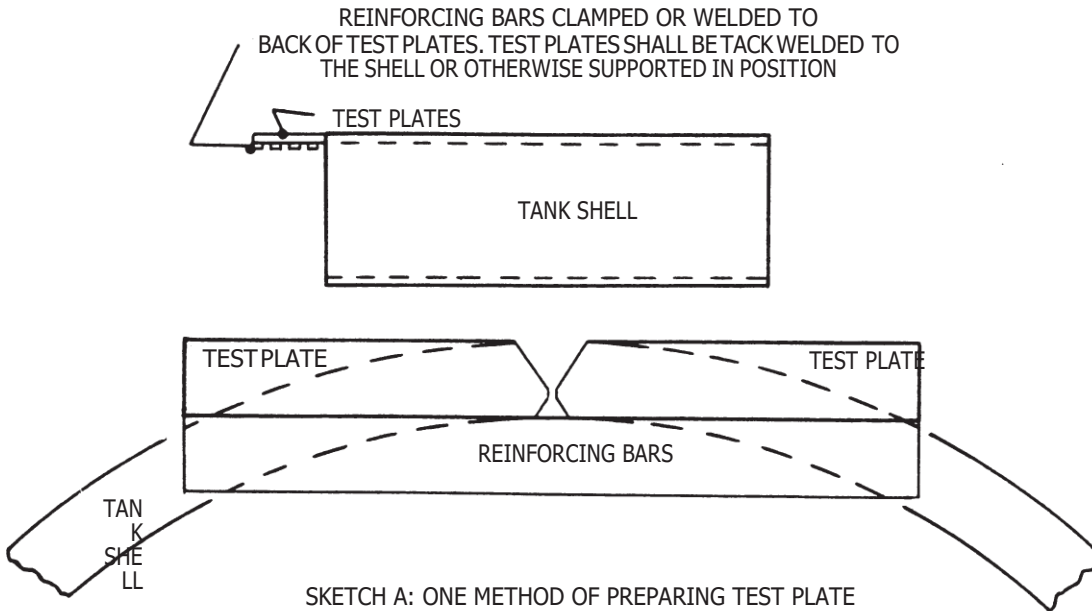
- NOTES:**
1. UNAFFECTED BASE METAL HARDNESS READINGS ARE OPTIONAL.
  2. IF BOTH BASE MATERIALS ARE IDENTICAL, HARDNESS READINGS ARE REQUIRED FOR ONE HEAT-AFFECTED ZONE
  3. MICROHARDNESS READINGS PER ASTM E-384
  4. MICROHARDNESS CONVERSIONS PER ASTM E-140

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**



SKETCH B: SUGGESTED ORDER OF REMOVAL OF SPECIMENS

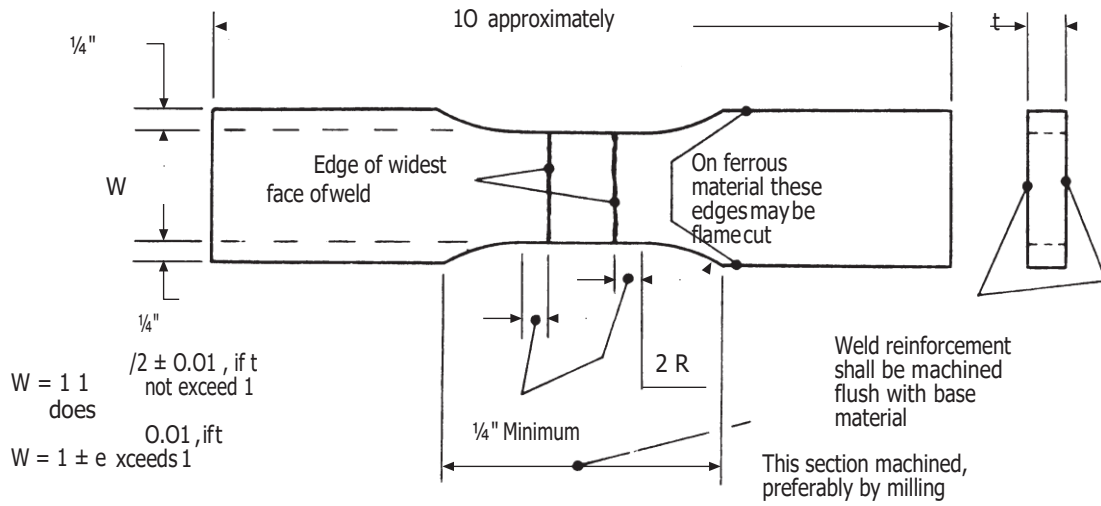
**Fig. W.1 Test plate**



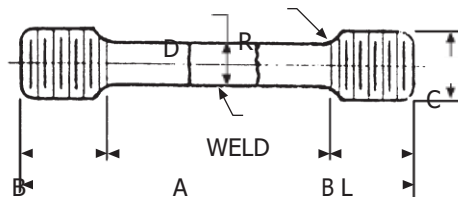
SKETCH B: SUGGESTED ORDER OF REMOVAL OF SPECIMENS

**Note:** All dimensions in mm. Appendix H must be followed when using SI units.

**Fig. W.1.1 Test plate—SI units**



SKETCH A: FLAT, REDUCED-SECTION TENSION SPECIMEN



SKETCH B: TURNED, REDUCED-SECTION TENSION SPECIMEN

	Standard Dimensions (in.)			
	(a) 0.505 Specimen	(b) 0.353 Specimen	(c) 0.252 Specimen	(d) 0.188 Specimen
A—reduced section length	See Note 4	See Note 4	See Note 4	See Note 4
B—end section length	1 3/8 approx.	1 1/8 approx.	7/8 approx.	1/2 approx.
C—end section diameter	3/4	1/2	3/8	1/4
D—diameter	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005	0.188 ± 0.003
R—radius of fillet	3/8 minimum	1/4 minimum	3/16 minimum	1/8 minimum

**NOTES:**

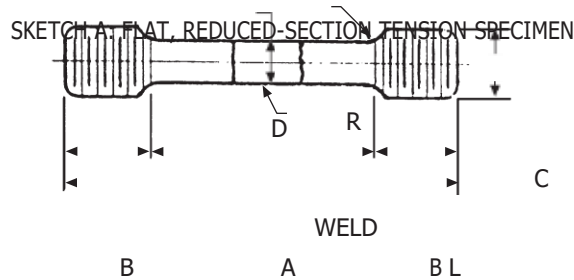
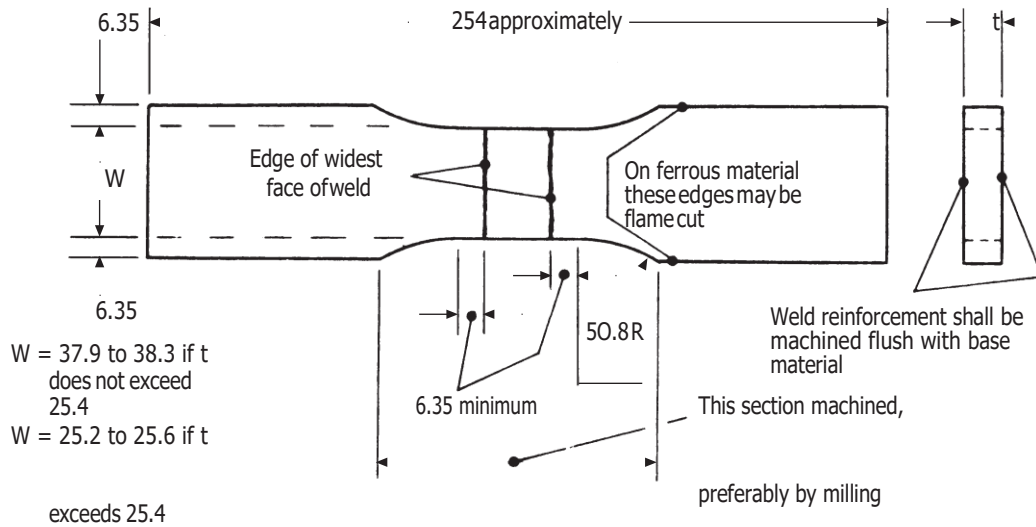
1. Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from test plate.
2. Weld should be in center of reduced section.
3. Where only a single specimen is required, the center of the specimen should be cut midway between the surfaces.
4. Reduced section "A" should be not less than width of weld plus two "D" in length.
5. The ends may be of any shape to fit the holders of the testing machine in such a way that the load is applied axially.

**Fig. W.2 Joint-tension specimens**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



SKETCH B: TURNED, REDUCED-SECTION TENSION SPECIMEN

**Note:** All dimensions in mm. Appendix H must be followed when using SI units.

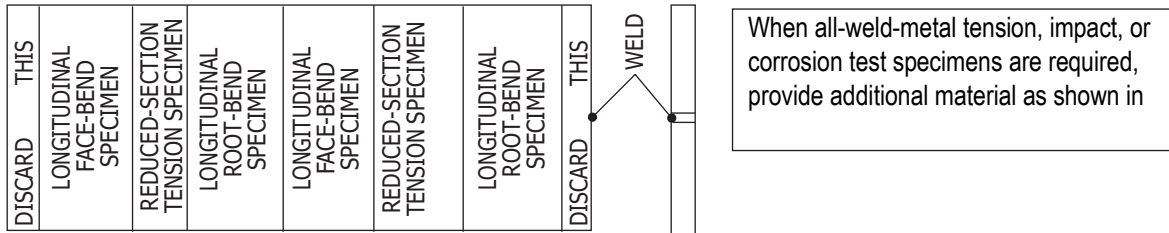
	Standard Dimensions (mm)			
	(a) 12.83 Specimen	(b) 8.97 Specimen	(c) 6.40 Specimen	(d) 4.78 Specimen
A—reduced section length	See Note 4	See Note 4	See Note 4	See Note 4
B—end section length	35 approx.	29 approx.	22 approx.	13 approx.
C—end section diameter	19.0	12.7	9.52	6.35
D—diameter	12.45 to 12.95	8.72 to 9.06	6.23 to 6.47	4.70 to 4.85
R—radius of fillet	9.82 minimum	6.38 minimum	4.76 minimum	3.18 minimum

**NOTES:**

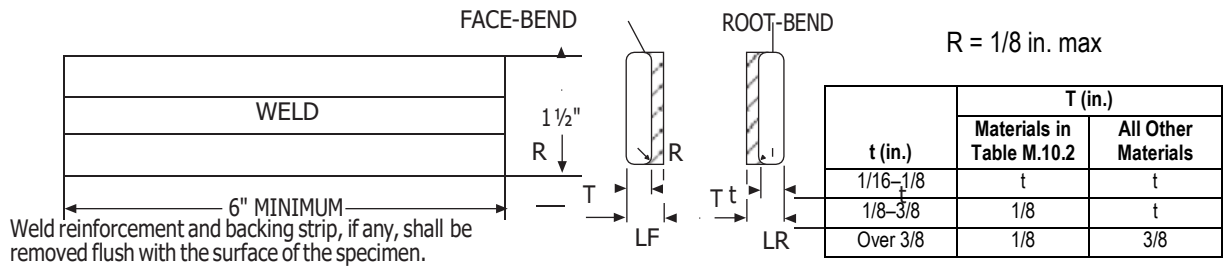
1. Use maximum diameter specimen (a), (b), (c), or (d) that can be cut from test plate.
2. Weld should be in center of reduced section.
3. Where only a single specimen is required, the center of the specimen should be cut midway between the surfaces.
4. Reduced section "A" should be not less than width of weld plus two "D" in length.
5. The ends may be of any shape to fit the holders of the testing machine in such a way that the load is applied axially.

**Fig. W.2.1 Joint-tension specimens—SI units**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

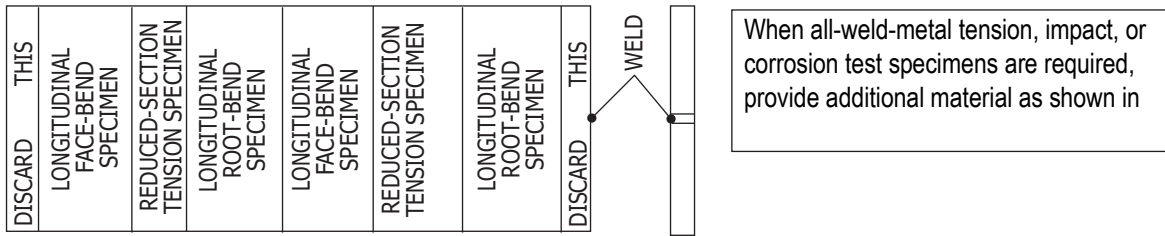


SKETCH A: SUGGESTED ORDER OF REMOVAL OF TEST SPECIMENS

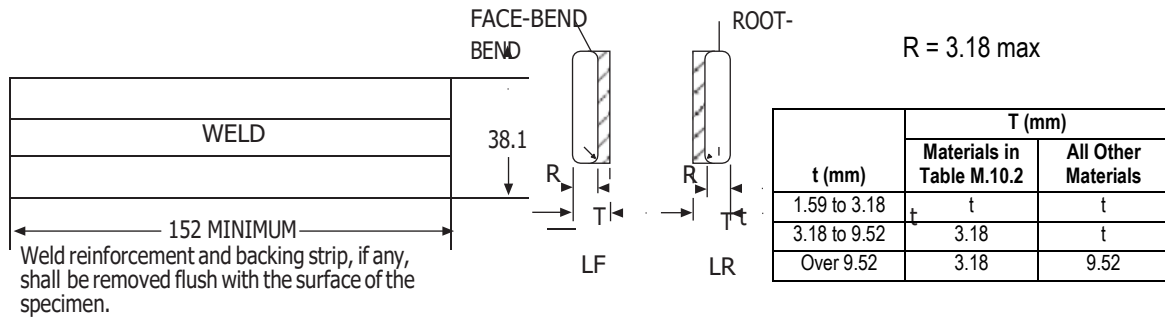


SKETCH B: LONGITUDINAL FACE-BEND AND LONGITUDINAL ROOT-BEND SPECIMENS

**Fig. W.3 Test plate and guided-bend test specimens for dissimilar metals**



SKETCH A: SUGGESTED ORDER OF REMOVAL OF TEST SPECIMENS



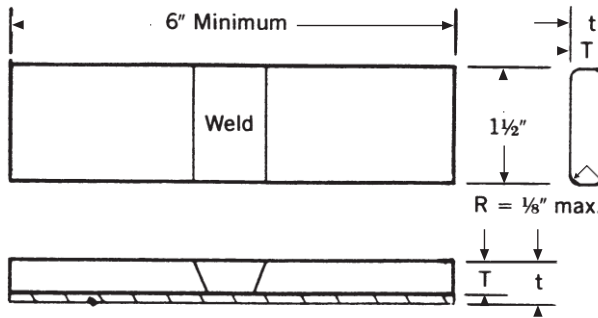
SKETCH B: LONGITUDINAL FACE-BEND AND LONGITUDINAL ROOT-BEND SPECIMENS

**Fig. W.3.1 Test plate and guided-bend test specimens for dissimilar metals—SI units**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



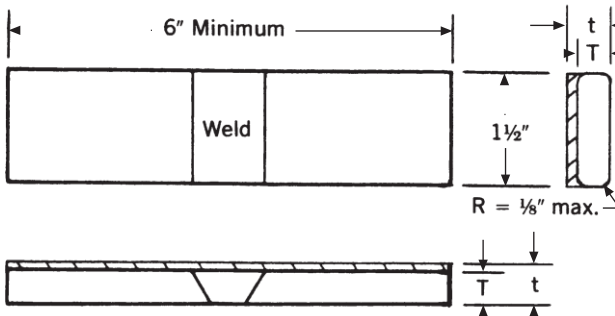
SKETCH A - FACE-BEND SPECIMEN

RELATION OF "T" AND "t" FOR FACE-BEND AND ROOT-BEND SPECIMENS		
"t" (inches)	THICKNESS "T" (inches)	
	FERROUS AND NONFERROUS (a) MATERIALS	ASTM B 209 ALLOY 6061
1/16 - 1/8	t	t
1/8 - 3/8	t	1/8
Over 3/8	3/8	1/8

Note a/ Except Alloy 6061

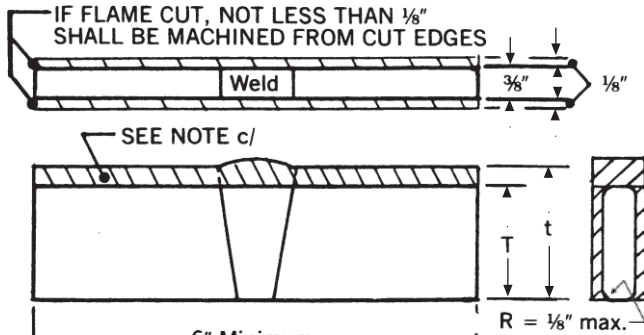
NOTES FOR FACE-BEND AND ROOT-BEND SPECIMENS:

1. Weld reinforcement, and backing strip if used, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified in the table above.



SKETCH B - ROOT-BEND SPECIMEN

CROSS-HATCHED AREAS INDICATE METAL REMOVAL BY MACHINING TO OBTAIN DIMENSION "T" AND THE THICKNESS OF SIDE-BEND SPECIMENS



SKETCH C - SIDE-BEND SPECIMEN

RELATION OF "T" AND "t" FOR SIDE-BEND SPECIMENS		
"t" (inches)	THICKNESS "T" (inches)	
	FERROUS AND NONFERROUS (a) MATERIALS	ASTM B 209 ALLOY 6061
3/8 - 1 1/2	t	t
Over 1 1/2	b/	1 1/2

Note a/ Except Alloy 6061

Note b/ For plates over 1 1/2 thick, cut specimen into approximately equal strips between 3/4 and 1 1/2 wide and test each strip.

Note c/ Machine specimen on this side when t exceeds 1 1/2"

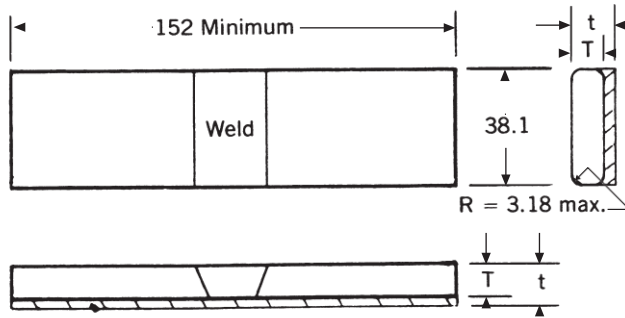
SKETCH D - SIDE-BEND SPECIMEN

FOR ASTM B 209 ALLOY 6061: This specimen to be the same as Sketch C except for specimen thickness and corner radius. The finished thickness shall be 1/8 rather than 3/8 and the radius shall be 1/16 max. rather than 1/8 max.

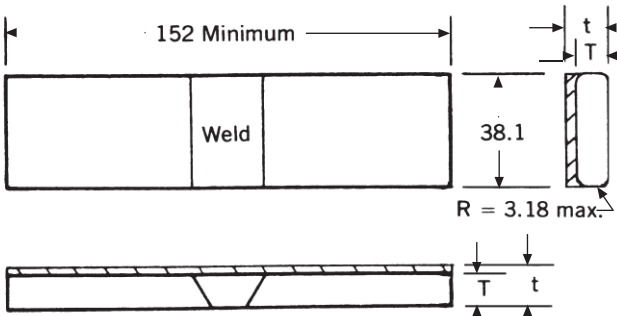
For longitudinal-face bend and longitudinal-root bend types of guided-bend specimens, see Fig. W.3, Sketch B.

Fig. W.4 Guided-bend test specimens

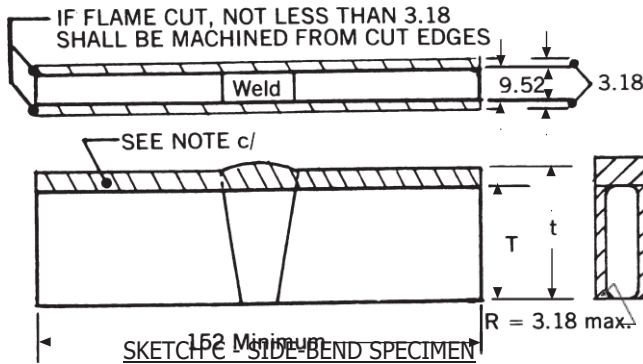
**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**



SKETCH A - FACE-BEND SPECIMEN



SKETCH B - ROOT-BEND SPECIMEN



SKETCH D - SIDE-BEND SPECIMEN

For longitudinal-face bend and longitudinal-root bend types of guided-bend specimens, see Fig. W.3, Sketch B.

FOR ASTM B 209 ALLOY 6061: This specimen to be the same as Sketch C except for specimen thickness and corner radius. The finished thickness shall be 3.18 rather than 9.52 and the radius shall be 1.59 max. rather than 3.18 max.

RELATION OF "T" AND "t" FOR FACE-BEND AND ROOT-BEND SPECIMENS		
"t" (mm)	THICKNESS "T" (mm)	
	FERROUS AND NONFERROUS (a/) MATERIALS	ASTM B 209 ALLOY 6061
1.59 to 3.18	t	t
3.18 to 9.52	t	3.18
Over 9.52	9.52	3.18

Note a/ Except Alloy 6061

NOTES FOR FACE-BEND AND ROOT-BEND SPECIMENS:

1. Weld reinforcement, and backing strip if used, shall be removed flush with the surface of the specimen. If a recessed ring is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the ring, except that in such cases the thickness of the finished specimen shall be that specified in the table above.

CROSS-HATCHED AREAS INDICATE METAL REMOVAL BY MACHINING TO OBTAIN DIMENSION "T" AND THE THICKNESS OF SIDE-BEND SPECIMENS

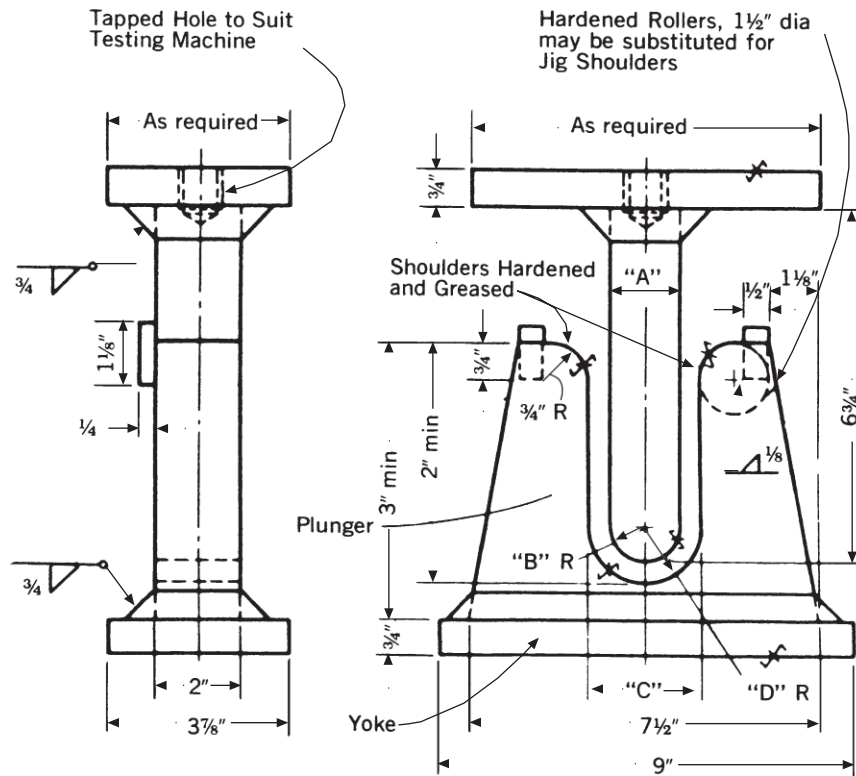
RELATION OF "T" AND "t" FOR SIDE-BEND SPECIMENS		
"t" (mm)	THICKNESS "T" (mm)	
	FERROUS AND NONFERROUS (a/) MATERIALS	ASTM B 209 ALLOY 6061
9.52 to 38.1	t	t
over 38.1	b/	38.1

Note a/ Except Alloy 6061

Note b/ For plates over 38.1 thick, cut specimen into approximately equal strips between 19 and 38.1 wide and test each strip.

Note c/ Machine specimen on this side when t exceeds 38.1

Fig. W.4.1 Guided-bend test specimens—SI units



Thickness of Specimen, (in.)	A (in.)	B (in.)	C (in.)	D (in.)
$3/8^{a/}$ $t^{a/}$	$1 \frac{1}{2}$ $4t$	$3/4$ $2t$	$2 \frac{3}{8}$ $6t + 1/8$	$1 \frac{3}{16}^{a/}$ $3t + 1/16^{a/}$
$1/8^{b/}$	$2 \frac{1}{16}$	$1 \frac{1}{32}$	$2 \frac{3}{8}$	$1 \frac{3}{16}^{b/}$
$3/8^{c/}$ $t^{d/}$	$2 \frac{1}{2}$ $6 \frac{2}{3}t$	$1 \frac{1}{4}$ $3 \frac{1}{3}t$	$3 \frac{3}{8}$ $8 \frac{2}{3}t + 1/8$	$1 \frac{11}{16}^{c/}$ $4 \frac{1}{3}t + 1/16^{d/}$
<u><math>3/8^{e/}</math></u>	<u>2</u>	<u>1</u>	<u><math>2 \frac{7}{8}</math></u>	<u><math>1 \frac{7}{16}^{e/}</math></u>

<sup>a/</sup> Use for all materials not otherwise indicated.

<sup>b/</sup> Use only for P-23 aluminum alloys.

<sup>c/</sup> Use only for P-25 aluminum alloys.

<sup>d/</sup> Use only for P-25 aluminum alloys where thickness, t, is less than 3/8 in.

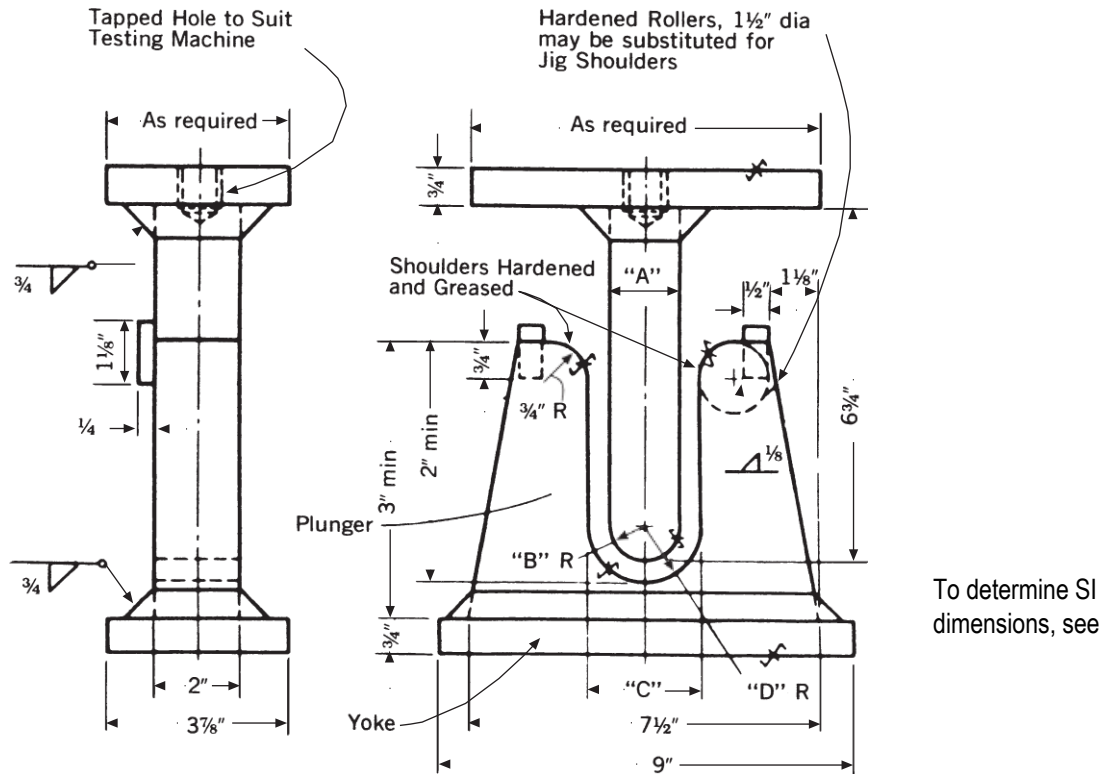
<sup>e/</sup> Steels from 50 ksi to 90 ksi yield

**Fig. W.5 Guided-bend test jig**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



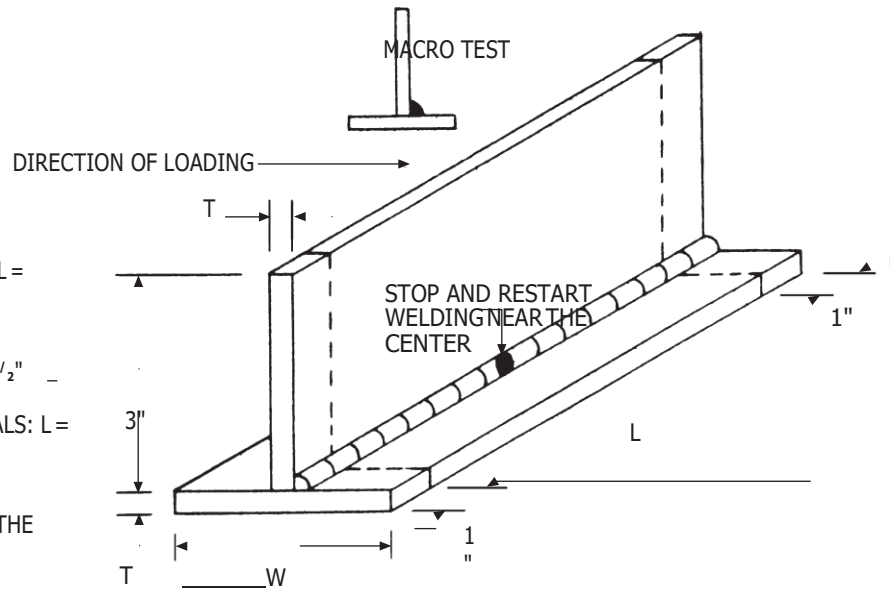
Thickness of Specimen, (mm)	A (mm)	B (mm)	C (mm)	D (mm)
9.52 <sup>a/</sup> t <sup>a/</sup>	38.1 4t	19.0 2t	60.3 6t + 3.18	30.2 <sup>a/</sup> 3t + 1.59 <sup>a/</sup>
3.18 <sup>b/</sup>	52.4	26.2	60.3	30.2 <sup>b/</sup>
9.52 <sup>c/</sup> t <sup>d/</sup>	63.5 6 2/3t	31.8 3 1/3t	85.7 8 2/3t + 3.18	42.9 <sup>c/</sup> 4 1/3t + 1.59 <sup>d/</sup>
10 <sup>e/</sup>	50	25	73	37 <sup>e/</sup>

- <sup>a/</sup> Use for all materials not otherwise indicated.
- <sup>b/</sup> Use only for P-23 aluminum alloys.
- <sup>c/</sup> Use only for P-25 aluminum alloys.
- <sup>d/</sup> Use only for P-25 aluminum alloys where thickness, t, is less than 9.52 mm.
- <sup>e/</sup> Steels from 345 MPa to 620 MPa yield

**Fig. W.5.1 Guided-bend test jig—SI units**

NOTES:

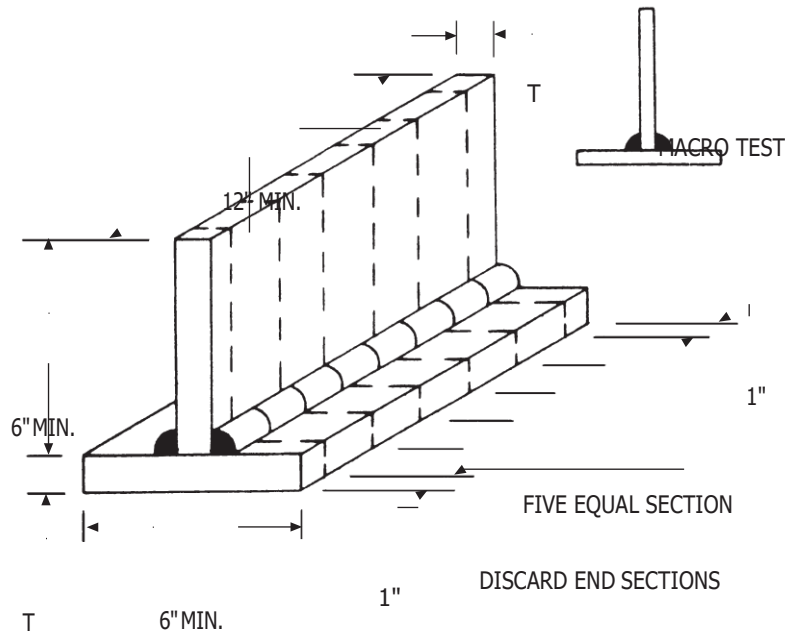
1. FOR FERROUS MATERIALS: L = 10"  
W = 3"  
T =  $\frac{3}{16}$ " to  $\frac{1}{2}$ "  
MAXIMUM FILLET SIZE =  $\frac{1}{2}$ "
2. FOR NONFERROUS MATERIALS: L = 4"  
W = 4"  
T =  $\frac{3}{16}$ " to  $\frac{3}{8}$ "  
MAXIMUM FILLET SIZE = THE SAME AS DIMENSION T



SKETCH A: FOR PERFORMANCE QUALIFICATION TEST

NOTE:

T = MAXIMUM THICKNESS OF BASE MATERIAL IN TANK AT POINT OF WELDING OR 1", WHICHEVER IS SMALLER

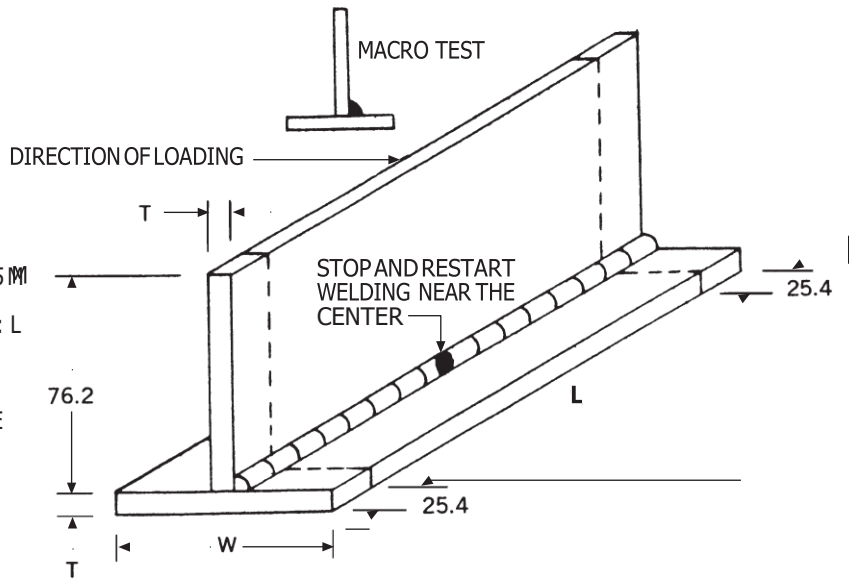


SKETCH B: FOR PROCEDURE QUALIFICATION TEST

**Fig. W.6 Fillet-welded tee-joint test specimens**

**NOTES:**

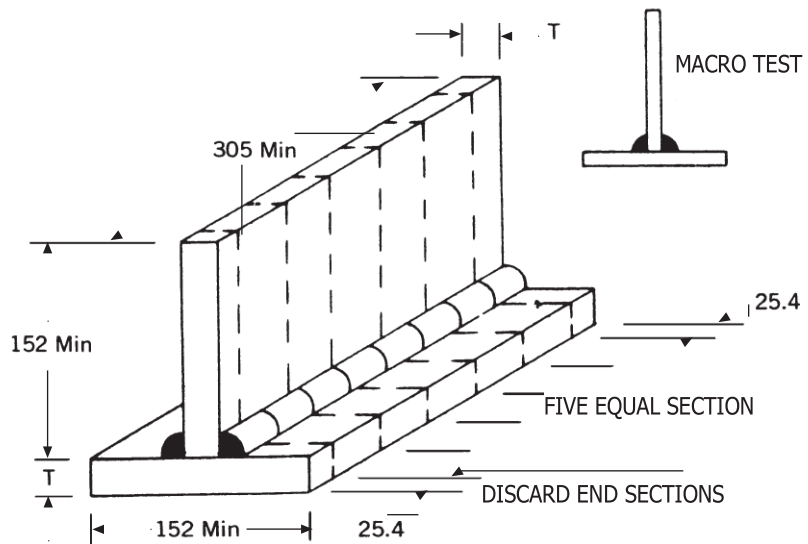
1. FOR FERROUS MATERIALS: L = 254 MM  
W = 76.2 MM  
T = .1875 TO 12.7 MM  
MAXIMUM FILLET SIZE = 6.35 MM
2. FOR NONFERROUS MATERIALS: L = 102 MM  
W = 102 MM  
T = 4.76 TO 9.52 MM  
MAXIMUM FILLET SIZE = THE SAME AS DIMENSION T.



SKETCH A: FOR PERFORMANCE QUALIFICATION TEST

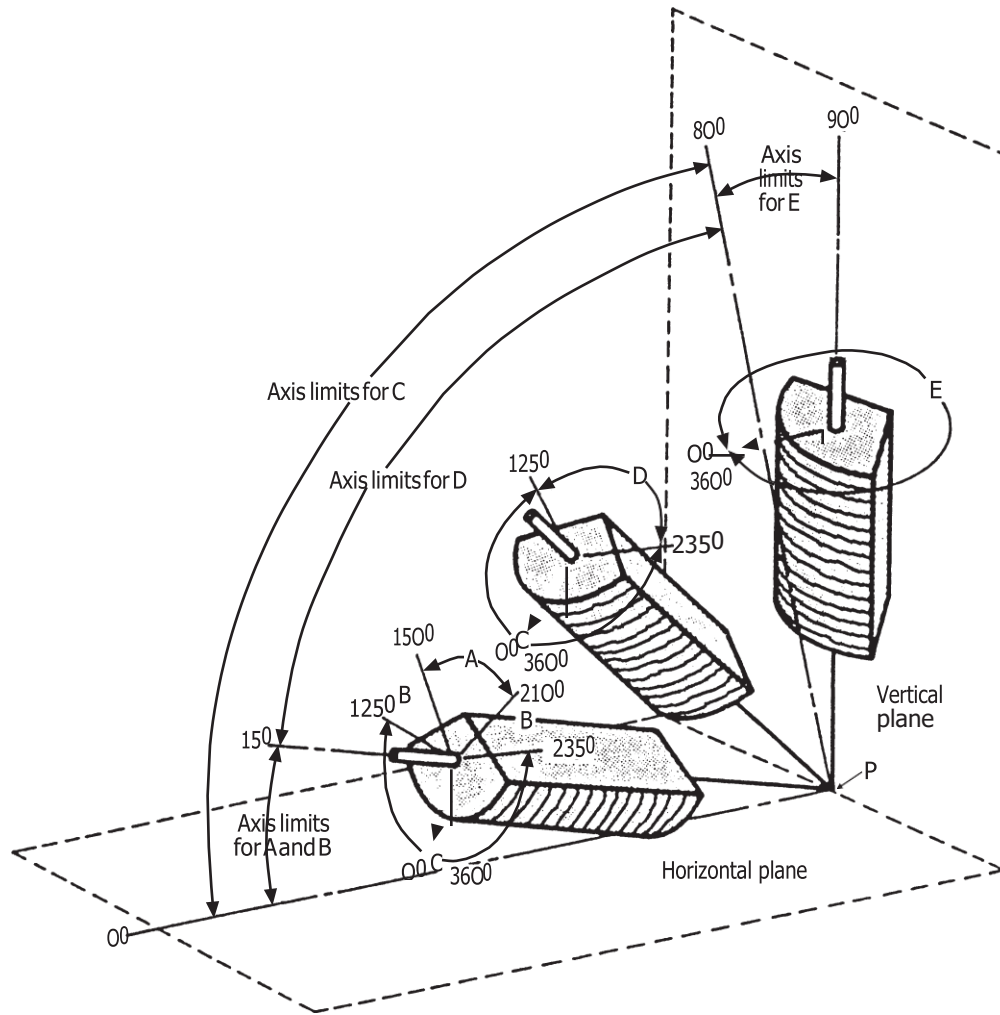
**NOTE:**

T = MAXIMUM THICKNESS OF BASE MATERIAL IN TANK AT POINT OF WELDING OR 25.4 MM, WHICHEVER IS SMALLER



SKETCH B: FOR PROCEDURE QUALIFICATION TEST

**Fig. W.6.1 Fillet-welded tee-joint test specimens—SI units**

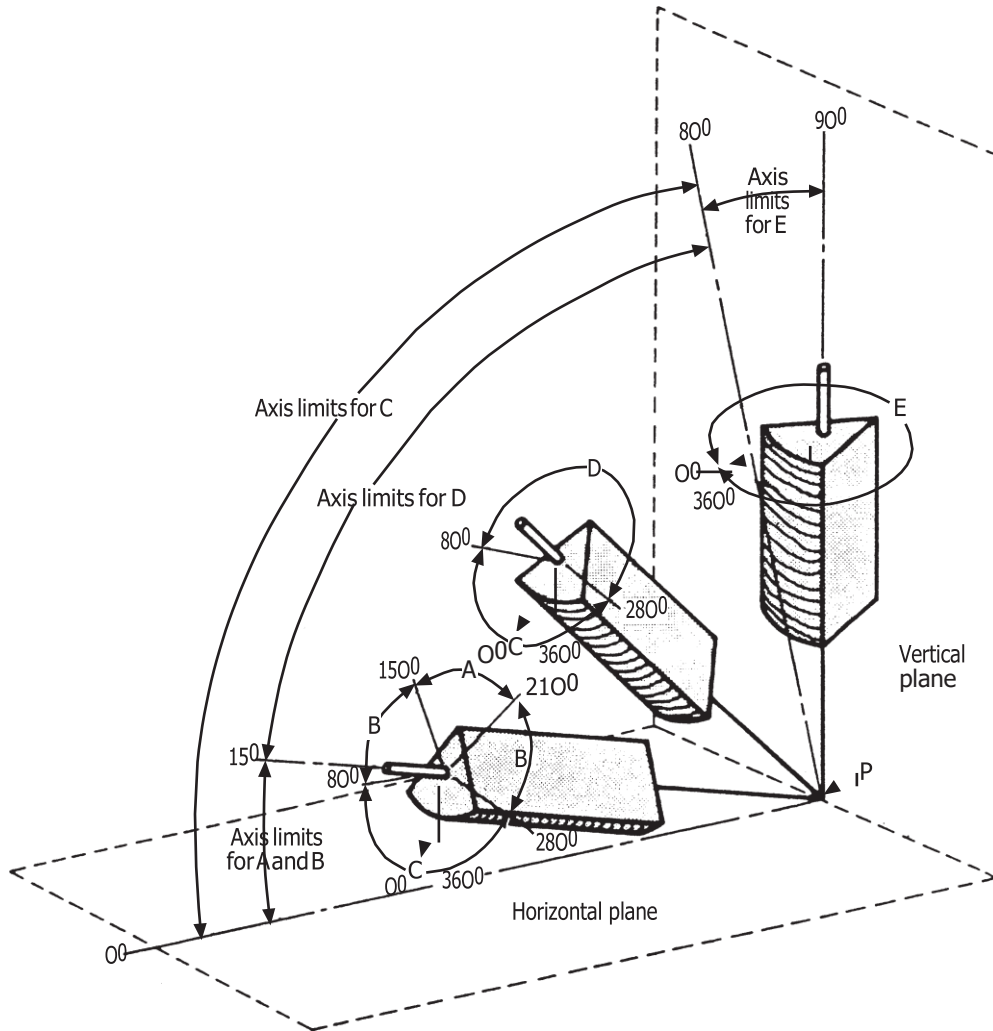


**Notes:**

1. The horizontal reference plane is always taken to lie below the weld under consideration.
2. The inclination of axis is measured from the horizontal reference plane toward the vertical reference plane.
3. The angle of rotation of the face is determined by a line perpendicular to the theoretical face of the weld which passes through the axis of the weld. The reference position (O0) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. When looking at point P, the angle of rotation of the face of the weld is measured in a clockwise direction from the reference position (O0).

<b>Tabulations of Positions of Fillet Welds</b>			
<b>Position</b>	<b>Diagram Reference</b>	<b>Inclination of Axis</b>	<b>Rotation of Face</b>
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	125° to 150° 210° to 235°
Overhead	C	0° to 80°	0° to 125° 235° to 360°
Vertical	D	15° to 80°	125° to 235°
	E	80° to 90°	0° to 360°

**Fig. W.7 Weld orientation and test positions—fillet welds**

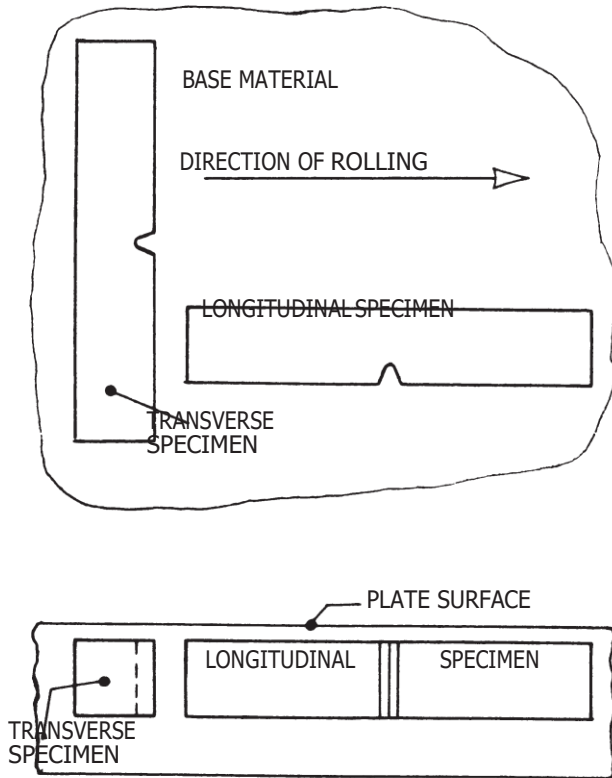


**Notes:**

1. The horizontal reference plane is always taken to lie below the weld under consideration.
2. The inclination of axis is measured from the horizontal reference plane toward the vertical reference plane.
3. The angle of rotation of the face is determined by a line perpendicular to the theoretical face of the weld which passes through the axis of the weld. The reference position (O0) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. When looking at point P, the angle of rotation of the face of the weld is measured in a clockwise direction from the reference position (O0).

<b>Tabulations of Positions of Groove Welds</b>			
<b>Position</b>	<b>Diagram Reference</b>	<b>Inclination of Axis</b>	<b>Rotation of Face</b>
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	80° to 150° 210° to 280°
Overhead	C	0° to 80°	0° to 80° 280° to 360°
Vertical	D	15° to 80°	80° to 280°
	E	80° to 90°	0° to 360°

**Fig. W.8 Weld orientation and test positions—groove welds**

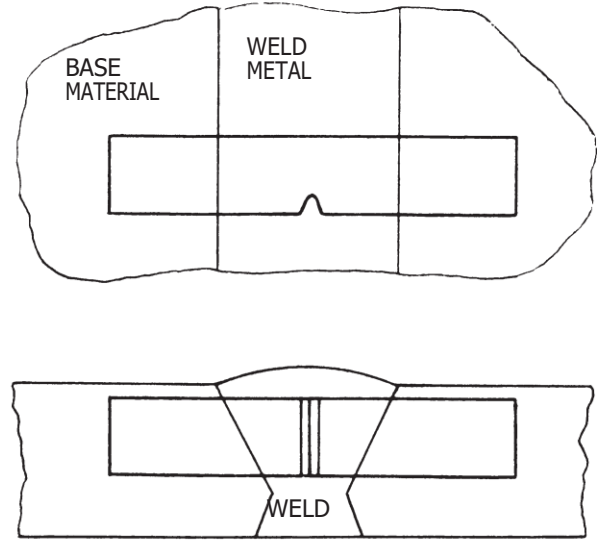


LOCATE SPECIMENS AS NEAR SURFACE AS PRACTICABLE FOR MATERIAL  $\frac{1}{2}$ " (12.7) AND THINNER. IF OVER  $\frac{1}{2}$ " (12.7) TAKE SPECIMEN MIDWAY BETWEEN SURFACE AND CENTER OF PLATE THICKNESS.

**SKETCH A-BASE MATERIAL**

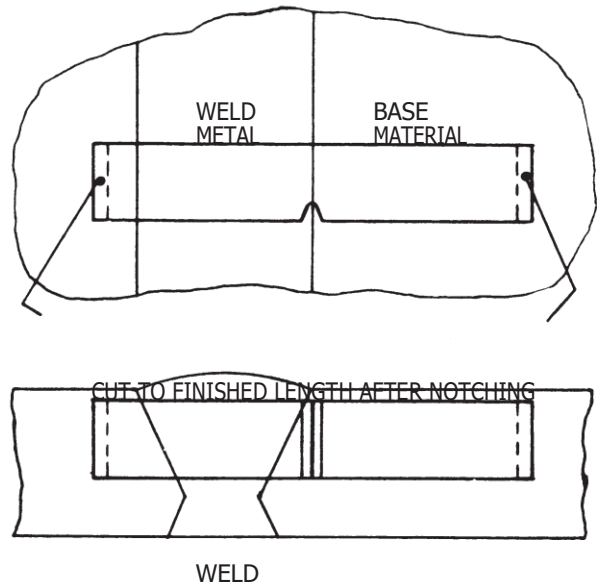
**NOTES:**

1. ALL NOTCHES CUT PERPENDICULAR TO PLATE SURFACE.
2. ALL COMMENTS APPLY TO FULL SIZE OR SUBSIZE SPECIMENS.
3. ALL COMMENTS APPLY TO TYPE A (CHARPY V-NOTCH), TYPE B (CHARPY KEYHOLE NOTCH), OR TYPE C (CHARPY U-NOTCH) SPECIMENS



LOCATE SPECIMEN WITHIN  $\frac{1}{16}$ " (1.59) OF PLATE SURFACE FOR MATERIAL 1 (25.4) AND THINNER. IF OVER 1 (25.4) THICK, TAKE SPECIMEN MIDWAY BETWEEN SURFACE AND CENTER OF PLATE THICKNESS.

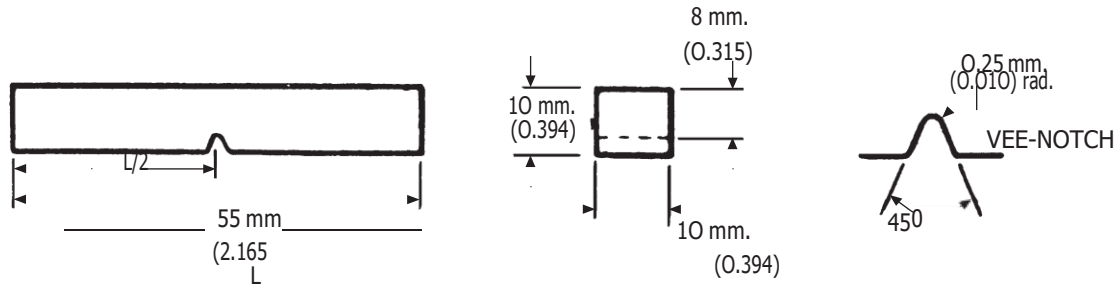
**SKETCH 8-WELD METAL**



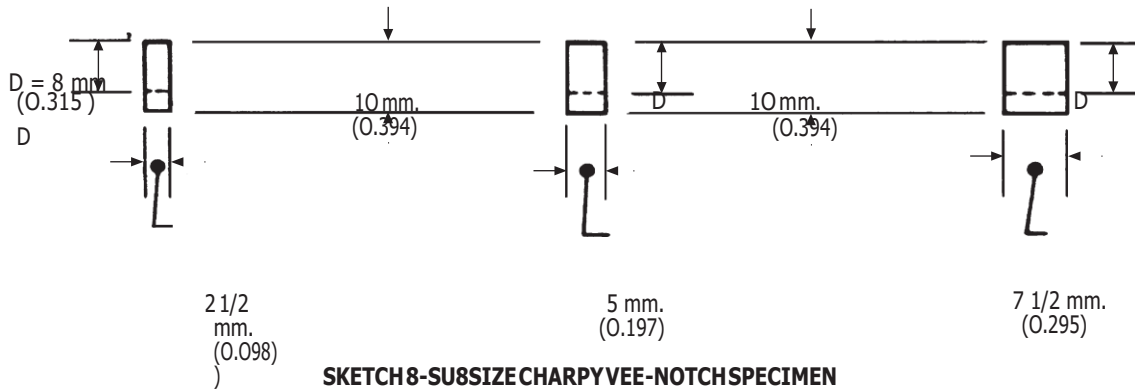
LOCATE SPECIMEN AS NEAR PLATE SURFACE AS PRACTICABLE. ETCH SPECIMEN AND LOCATE NOTCH IN HEAT-AFFECTED ZONE.

**SKETCH C-HEAT-AFFECTED ZONE**

**Fig. W.9 Impact test specimen location and orientation**



**SKETCH A-FULL SIZE CHARPY VEE-NOTCH SPECIMEN**



**SKETCH 8-SUBSIZE CHARPY VEE-NOTCH SPECIMEN**

Permissible Dimensional Variations	
Angle between adjacent sides	90 degrees +10 minutes
Cross-section dimensions	± 0.025 mm (0.001")
Length of section (L)	+0, -2.5 mm (0.100")
Centering of notch (L/2)	±1 mm (0.039")
Angle of notch	±1 degree
Radius of notch	±0.025 mm (0.001")
Dimension to bottom of notch	±0.025 mm (0.001")
Surface finish requirements (AA = arithmetical average)	2 μ (63 microinches AA) on notched surface and opposite face; 4 μ (125 microinches AA) on other two surfaces.

**Fig. W.10 Type A Charpy (simple beam) impact test specimen dimensions**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**Suggested Format for Welding Procedure Specification (WPS)**

Company Name \_\_\_\_\_ By: \_\_\_\_\_  
 Welding Procedure Spec. No. \_\_\_\_\_ Rev. Date: \_\_\_\_\_ Supporting PQR No.(s) \_\_\_\_\_  
 No. \_\_\_\_\_ Date: \_\_\_\_\_

Welding Process(es) \_\_\_\_\_ Type(s) \_\_\_\_\_  
 (Automatic, Manual, Machine, or Semi-Auto)

<p><b>JOINTS</b></p> <p>Joint Design _____                  Backing (Yes) _____ (No) _____                  Backing Material (Type) _____                  (Refer to both backing and retainers)</p> <p>← Metal ← Nonfusing Metal                  ← Nonmetallic ← Other</p> <p>Sketches, production drawings, weld symbols or written description should show the general arrangement of the parts to be welded. Where applicable, the root spacing and the details of weld groove may be specified.</p> <p>(At the option of the manufacturer, sketches may be attached to illustrate joint design, weld layers and bead sequence, e.g., for notch toughness procedures, for multiple process procedures, etc.)</p>	<p align="center"><b>DETAILS</b></p>
<p><b>*BASE METALS</b></p> <p>P-No. _____ to P-No. _____                  OR                  Specification Type and Grade _____                  to Specification Type and Grade _____                  OR                  Chemical Analysis and Mechanical Properties _____                  to Chemical Analysis and Mechanical Properties _____</p> <p>Thickness Range:                  Base Metal: _____ Groove _____ Fillet _____                  Other _____</p>	
<p><b>*FILLER METALS</b></p> <p>Specification No. _____                  AWS No. (Class) _____                  F-No. _____                  A-No. _____                  Size of Filler Metals _____                  Deposited Weld Metal _____                  Electrode-Flux (Class) _____                  Flux Trade Name _____                  Consumable Insert _____                  Other _____</p>	
<p>*Each base metal-filler metal combination should be recorded individually.</p>	

**Fig. W.11 Suggested format for welding procedure specification (WPS)**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

WPS No. \_\_\_\_\_ Rev. \_\_\_\_\_

<b>POSITIONS</b> Position(s) of Groove _____ Welding Progression: Up _____ Down _____ Position(s) of Fillet _____				<b>POSTWELD HEAT TREATMENT</b> Temperature Range _____ Time Range _____																		
<b>PREHEAT</b> Preheat Temperature, Min. _____ Interpass Temperature, Max. _____ Preheat Maintenance _____ (Continuous or special heating, where applicable, should be recorded)				<b>GAS</b> <table style="width:100%; border-collapse: collapse;"> <tr> <td style="width: 50%;"></td> <td align="center" colspan="2">Percent Composition</td> </tr> <tr> <td></td> <td align="center">Gas(es)</td> <td align="center">Mixture Flow Rate Shielding</td> </tr> <tr> <td colspan="3">_____</td> </tr> <tr> <td colspan="3">Trailing _____</td> </tr> <tr> <td colspan="3">Backing _____</td> </tr> </table>					Percent Composition			Gas(es)	Mixture Flow Rate Shielding	_____			Trailing _____			Backing _____		
	Percent Composition																					
	Gas(es)	Mixture Flow Rate Shielding																				
_____																						
Trailing _____																						
Backing _____																						
<b>ELECTRICAL CHARACTERISTICS</b> Current AC or DC _____ Polarity _____ Amps (Range) _____ Volts (Range) _____ (Amps and volts range should be recorded for each electrode size, position and thickness, etc. This information may be listed in a tabular form similar to that shown below) Tungsten Electrode Size & Type _____ (Pure Tungsten, 2% Thoriated, etc.) Mode of Metal Transfer for GMAW _____ (Spray, arc, short-circuited arc, etc.) Electrode Wire Feed Speed Range _____																						
<b>TECHNIQUE</b> String or Weave Bead _____ Orifice or Gas Cup Size _____ Initial and Interpass Cleaning (Brushing, Grinding, etc.) _____ _____ Method of Back Gouging _____ Oscillation _____ Contact Tube to Work Distance _____ Multiple or Single Pass (per side) _____ Multiple or Single Electrodes _____ Travel Speed (Range) _____ Peening _____ Other _____																						
Weld Layer(s)	Process	Filler Metal		Current		Voltage Range	Travel Speed Range	OTHER (e.g. Remarks, Comments, Hot Wire Addition, Technique, Torch Angle, etc.)														
		Class	Diameter	Type Polarity	Amperage Range																	

**Fig. W.11 Suggested format for welding procedure specification (WPS) (concluded)**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

**Suggested Format for Procedure Qualification Record (PQR)**

PQR No. \_\_\_\_\_

Company Name \_\_\_\_\_

Welding Procedure Spec. No. \_\_\_\_\_

Date: \_\_\_\_\_

Welding Process(es) \_\_\_\_\_

Types (Manual, Automatic, Semi-Automatic) \_\_\_\_\_

<p><b>JOINTS</b></p> <p align="center">Groove Design of Test Coupon (For combination qualifications, the deposited weld metal thickness shall be recorded for each filler metal or process used.)</p>									
<p><b>BASE METALS</b></p> <p>Material Specification _____</p> <p>Type or Grade _____</p> <p>P-No. _____ to P-No. _____</p> <p>Thickness of Test Coupon _____</p> <p>Diameter of Test Coupon _____</p> <p>Other _____</p> <p>_____</p> <p>_____</p> <p>_____</p>	<p><b>POSTWELD HEAT TREATMENT</b></p> <p>Temperature _____</p> <p>Time _____</p> <p>Other _____</p> <p>_____</p> <p><b>GAS</b></p> <table border="0" style="margin-left: auto; margin-right: auto;"> <tr> <td></td> <td align="center" colspan="3">Percent Composition</td> </tr> <tr> <td></td> <td align="center">Gas(es)</td> <td align="center">Mixture</td> <td align="center">Flow Rate</td> </tr> </table> <p>Shielding _____ Trailing Backing _____</p> <p>_____</p>		Percent Composition				Gas(es)	Mixture	Flow Rate
	Percent Composition								
	Gas(es)	Mixture	Flow Rate						
<p><b>FILLER METALS</b></p> <p>AWS Specification _____</p> <p>AWS Classification _____</p> <p>Filler Metal F-No. _____</p> <p>Weld Metal Analysis A-No. _____</p> <p>Size of Filler Metal _____</p> <p>Other _____</p> <p>_____</p> <p>Deposited Weld Metal _____</p>	<p><b>ELECTRICAL CHARACTERISTICS</b></p> <p>Current _____</p> <p>Polarity _____</p> <p>Amps _____ Volts _____</p> <p>Tungsten Electrode Size _____</p> <p>Other _____</p> <p>_____</p>								
<p><b>POSITION</b></p> <p>Position of Groove _____</p> <p>Weld Progression (Upward, Downward) _____</p> <p>Other _____</p> <p>_____</p> <p>_____</p>	<p><b>TECHNIQUE</b></p> <p>Travel Speed _____</p> <p>String of Weave Bead _____</p> <p>Oscillation _____</p> <p>Multipass or Single Pass (per side) _____</p> <p>Single or Multiple Electrodes _____</p> <p>Other _____</p> <p>_____</p>								
<p><b>PREHEAT</b></p> <p>Preheat Temperature _____</p> <p>Interpass Temperature _____</p> <p>Other _____</p>	<p>_____</p> <p>_____</p> <p>_____</p>								

Revised 3/16/88

Page 1 of 2

**Fig. W.12 Suggested format for procedure qualification record (PQR)**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

PQR No. \_\_\_\_\_

REDUCED SECTION TENSILE SPECIMEN TESTS

Specimen No.	Width	Thickness	Area	Ultimate Total Load lb.	Ultimate Unit Stress psi	Type of Failure & Location

ALL—WELD—METAL TENSION SPECIMEN TEST

Type & Figure No.	Diameter in.	Area sq. In.	ULTIMATE TENSILE STRENGTH		YIELD STRENGTH (0.2% offset) psi	ELONGATION (%)	REDUCTION OF AREA (%)
			Total Load lb.	Unit Stress psi			

GUIDED BEND TESTS

Type and Figure No.	Result

CHARPY IMPACT TESTS

Specimen No.	Notch Location	Notch Type	Test Temperature	Impact Values	Percent Shear	Lateral Expansion Mils

FILLET WELD TESTS

Result-Satisfactory: Yes      No      Penetration into Parent Metal: Yes      No

Macro-Results \_\_\_\_\_

OTHER TESTS

Type of Test \_\_\_\_\_

Deposit Analysis \_\_\_\_\_

Other \_\_\_\_\_

Welder's Name \_\_\_\_\_ Clock No. \_\_\_\_\_ Stamp No. \_\_\_\_\_

Tests Conducted By: \_\_\_\_\_ Laboratory Test No. \_\_\_\_\_

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of Appendix W.

Manufacturer: \_\_\_\_\_

Date \_\_\_\_\_ By: \_\_\_\_\_

**Fig. W.12 Suggested format for procedure qualification record (PQR) (concluded)**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W

<b>RECORD OF WELDER PERFORMANCE QUALIFICATION TEST</b>			
Welder's name _____ Clock number _____ Stamp no. _____			
Welding process(es) used _____ Type _____			
Identification of WPS followed by welder during welding of test coupon _____			
Base material(s) welded _____ Thickness _____			
<b>← Manual or Semiautomatic Variables for Each Process (W12.04)</b>		Used	Qualified
Backing (metal, weld metal, welded from both sides, flux, etc.)		_____	_____
P-No. to P-No.		_____	_____
Filler metal specification (AWS) / Classification		_____	_____
Filler metal F-No.		_____	_____
Consumable insert Weld thickness		_____	_____
Welding position (1G, 5G, etc.)		_____	_____
Progression (uphill/downhill)		_____	_____
Backing gas for GTAW		_____	_____
GMAW transfer mode		_____	_____
GTAW welding current type/polarity		_____	_____
<b>← Machine Welding Variables for the Process Used W12.02</b>			
<b>Guided Bend Test Results</b>			
Guided Bend Tests Type:    ← Fig W5 Sketch C (Side)			
← Fig W5 Sketches A & B (Trans. R & F)			
← Fig W5 Sketch B (Long, R & F)			
Type (Side, Root, Face)	Result	Type (Side, Root, Face)	Result
Visual examination (see paragraphs W15.3, 15.4, 15.5, and 15.9)		Acceptable	← Yes   ← No
Radiographic test results _____			
(For alternative qualification of groove welds by radiography)			
Fillet weld _____ Fracture test _____		Length and percent of defects _____ in.	
Macro test fusion _____ Fillet leg size _____ in. x _____ in.		Concavity/convexity _____ in.	
Welding test conducted by _____			
Mechanical tests conducted by _____		Laboratory test no. _____	
We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of Appendix W.			
Date _____		Organization _____	
		By _____	

**Fig. W.13 Record of Welder Performance Qualification Test**

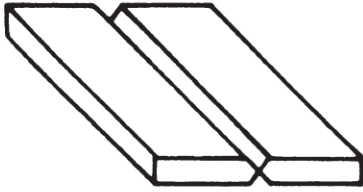


Plate horizontal. Axis of weld horizontal.  
FLAT POSITION 1G

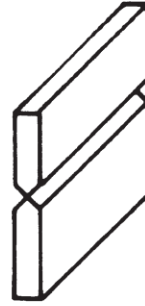


Plate vertical. Axis of weld horizontal.  
HORIZONTAL POSITION 2G

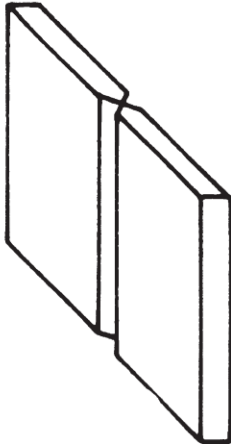


Plate vertical.  
Axis of weld vertical.

VERTICAL POSITION 3G

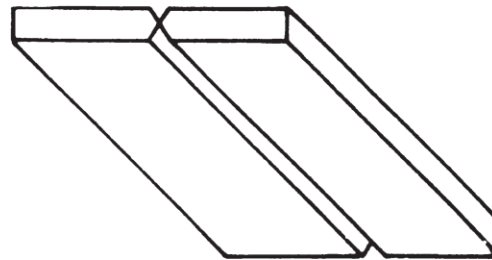


Plate and axis of weld horizontal. Weld made from below.

OVERHEAD POSITION 4G

**Fig. W.14 Positions of test plates for butt groove welds (joint design optional)**

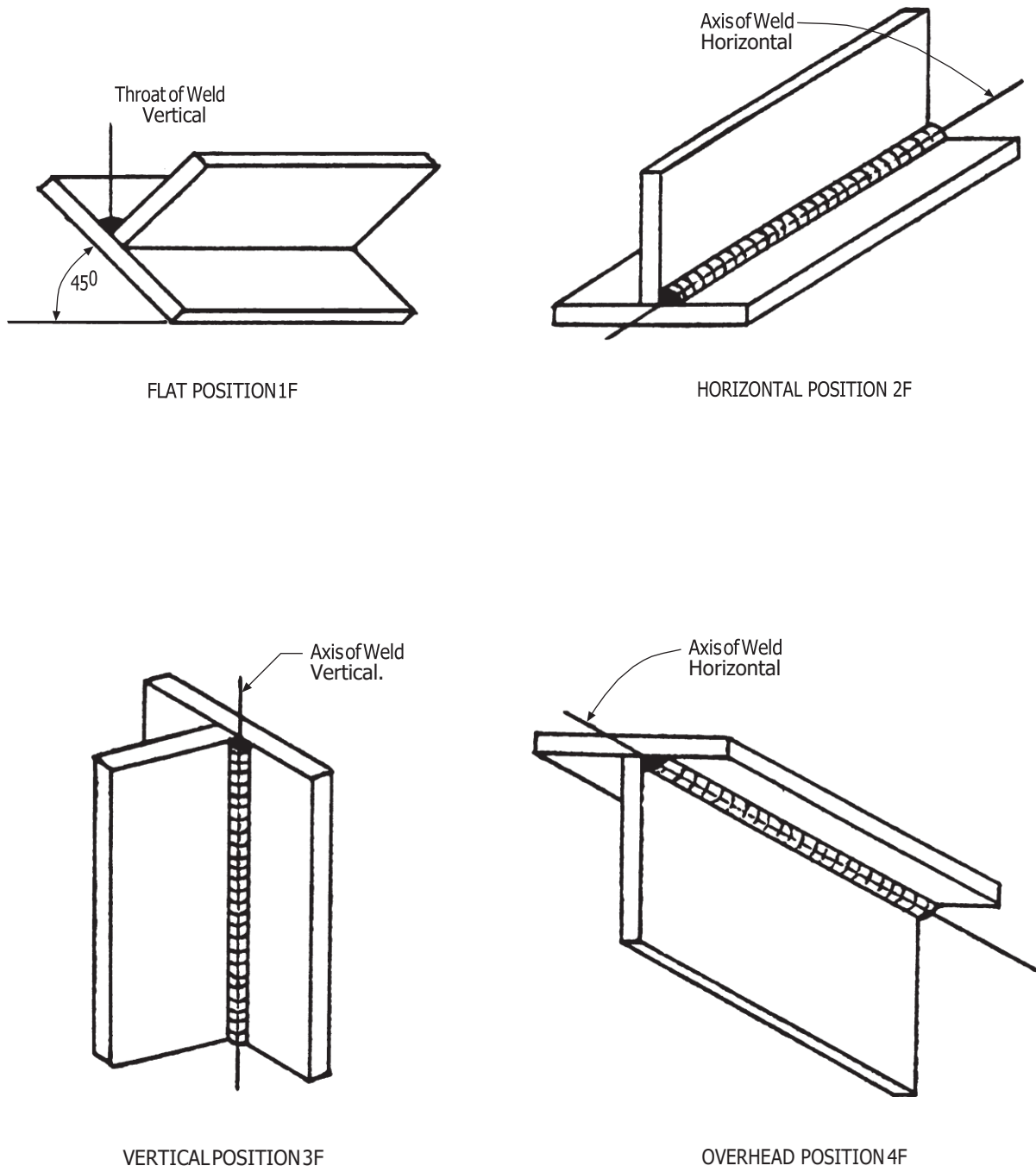
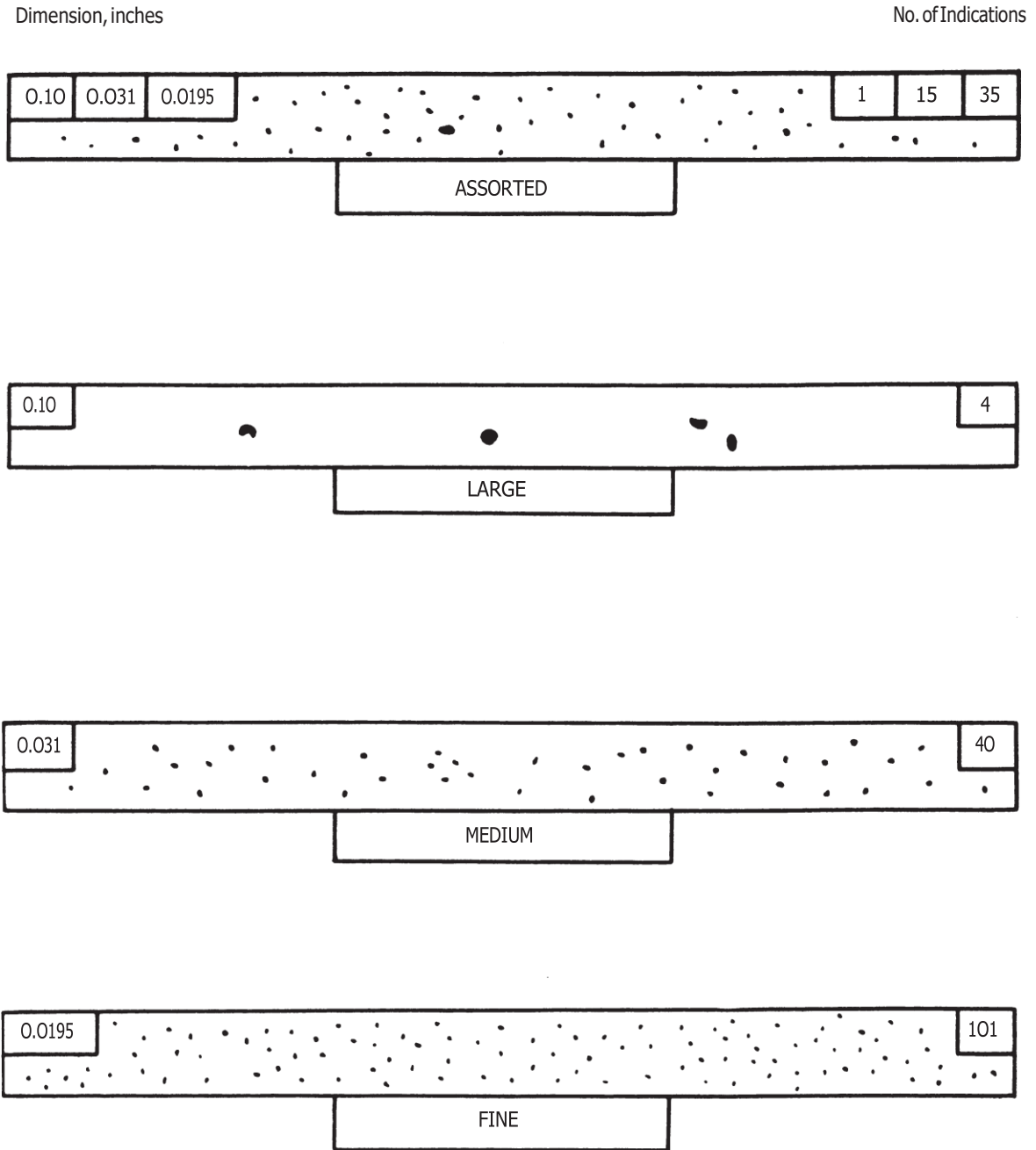


Fig. W.15 Positions of test plates for fillet welds

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 6-IN. LENGTH OF WELD.  
1/2-IN. WELD THICKNESS  
TOTAL INDICATION AREA PERMITTED IS 0.030 SQ IN.

**Fig. W.16 Rounded indication charts**

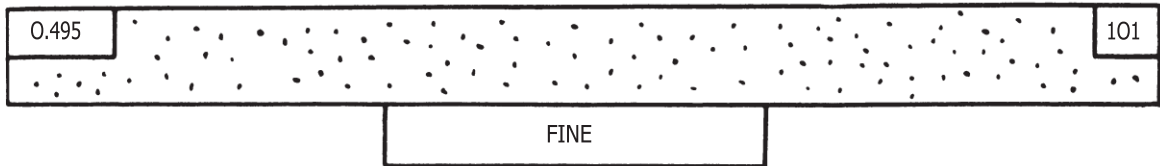
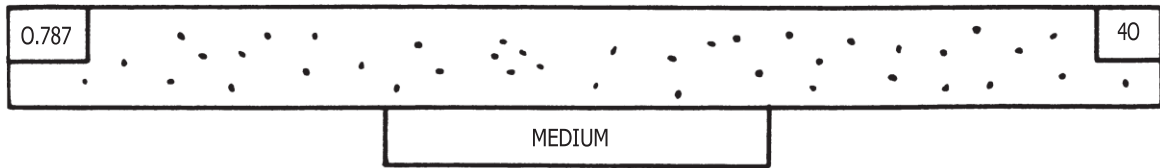
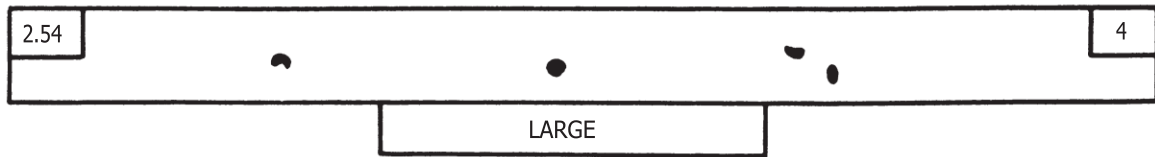
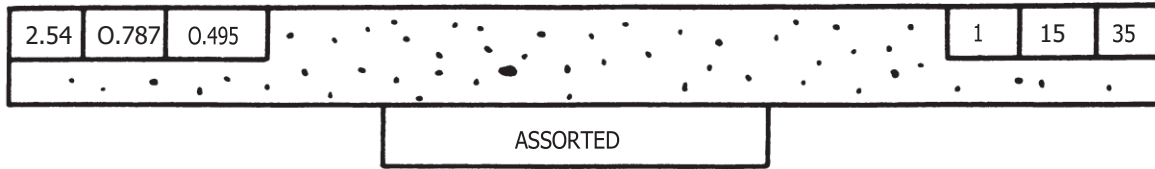
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Specifications for Tank Cars**

M-1002

APPENDIX W

Dimension, millimeters

No. of Indications



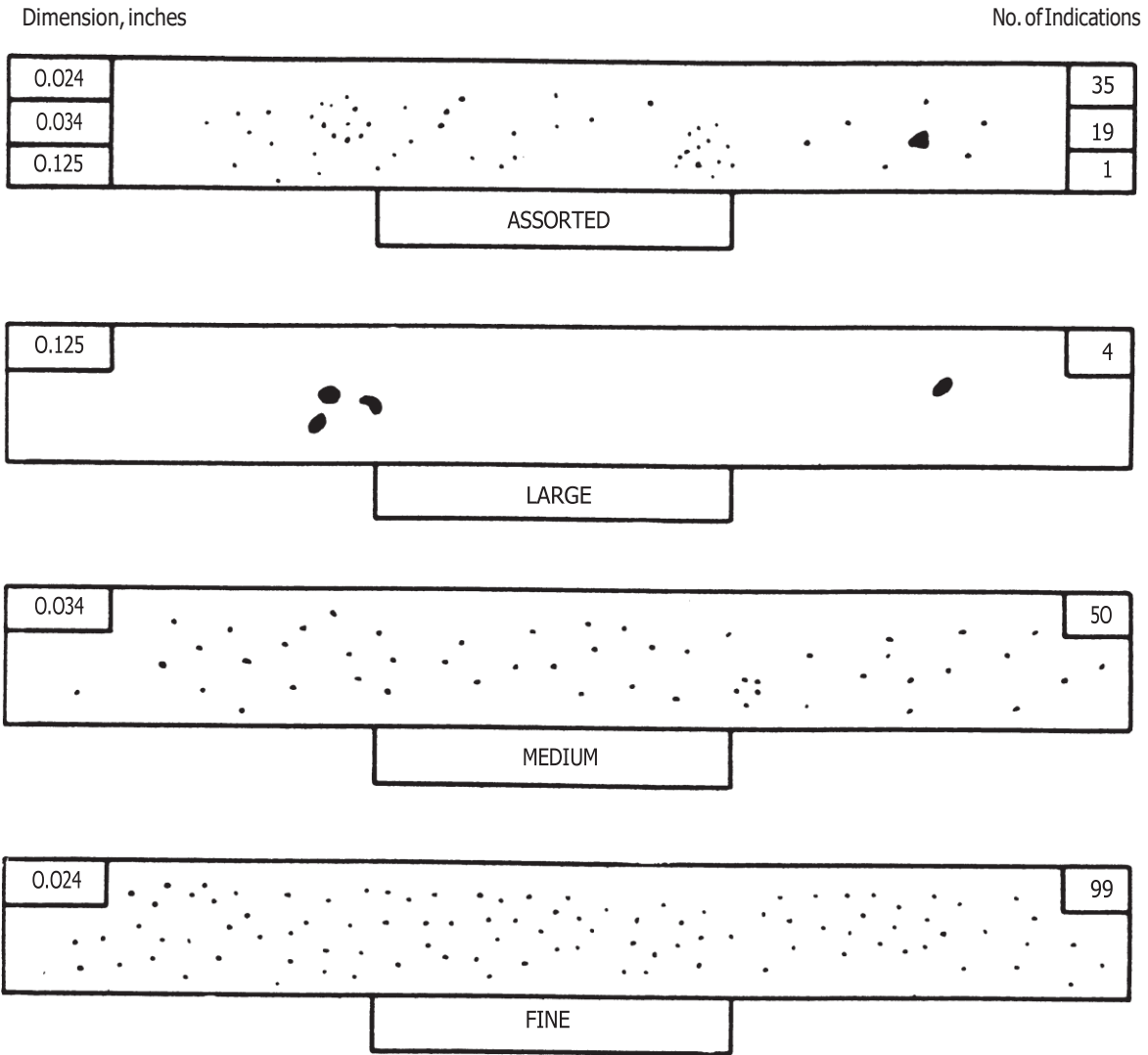
TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 152 MM LENGTH OF WELD.  
12.7 MM WELD THICKNESS  
TOTAL INDICATION AREA PERMITTED IS 19.4 SQ. MM.

**Fig. W.16.1 Rounded indication charts—SI units**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY SIX INCH LENGTH OF WELD. THREE  
QUARTER INCH WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS .045 SQ. IN.

**Fig. W.17 Rounded indication charts**

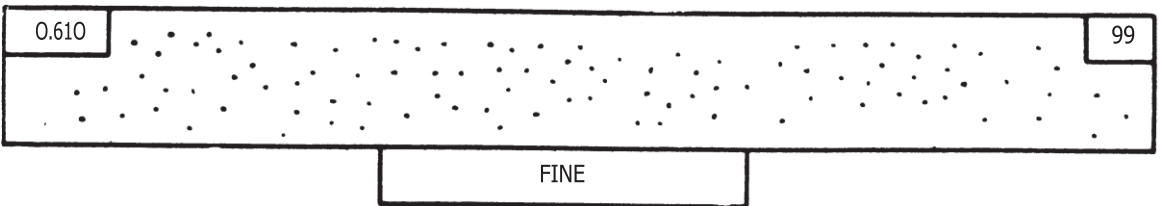
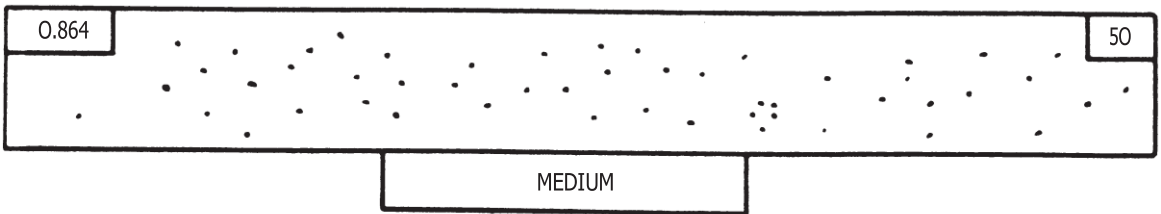
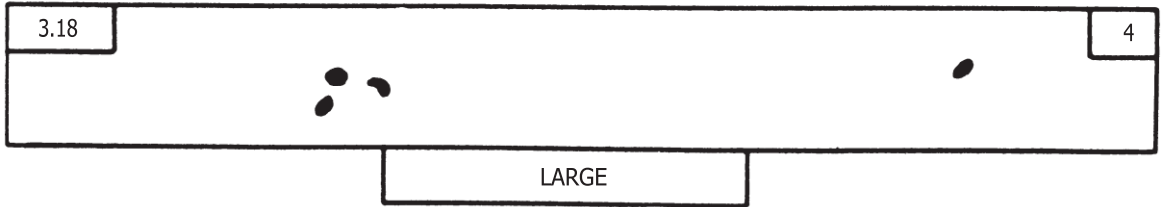
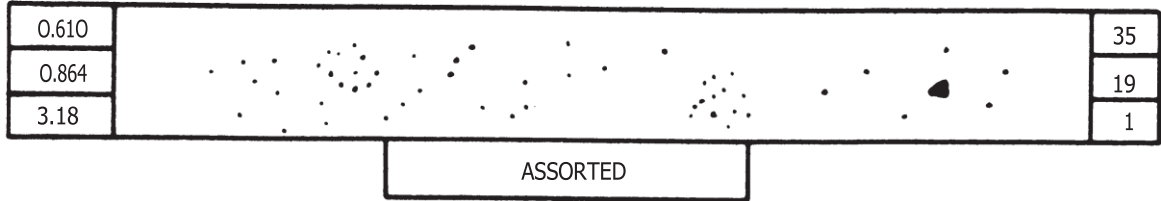
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Specifications for Tank Cars**

M-1002

APPENDIX W

Dimension, millimeters

No. of Indications



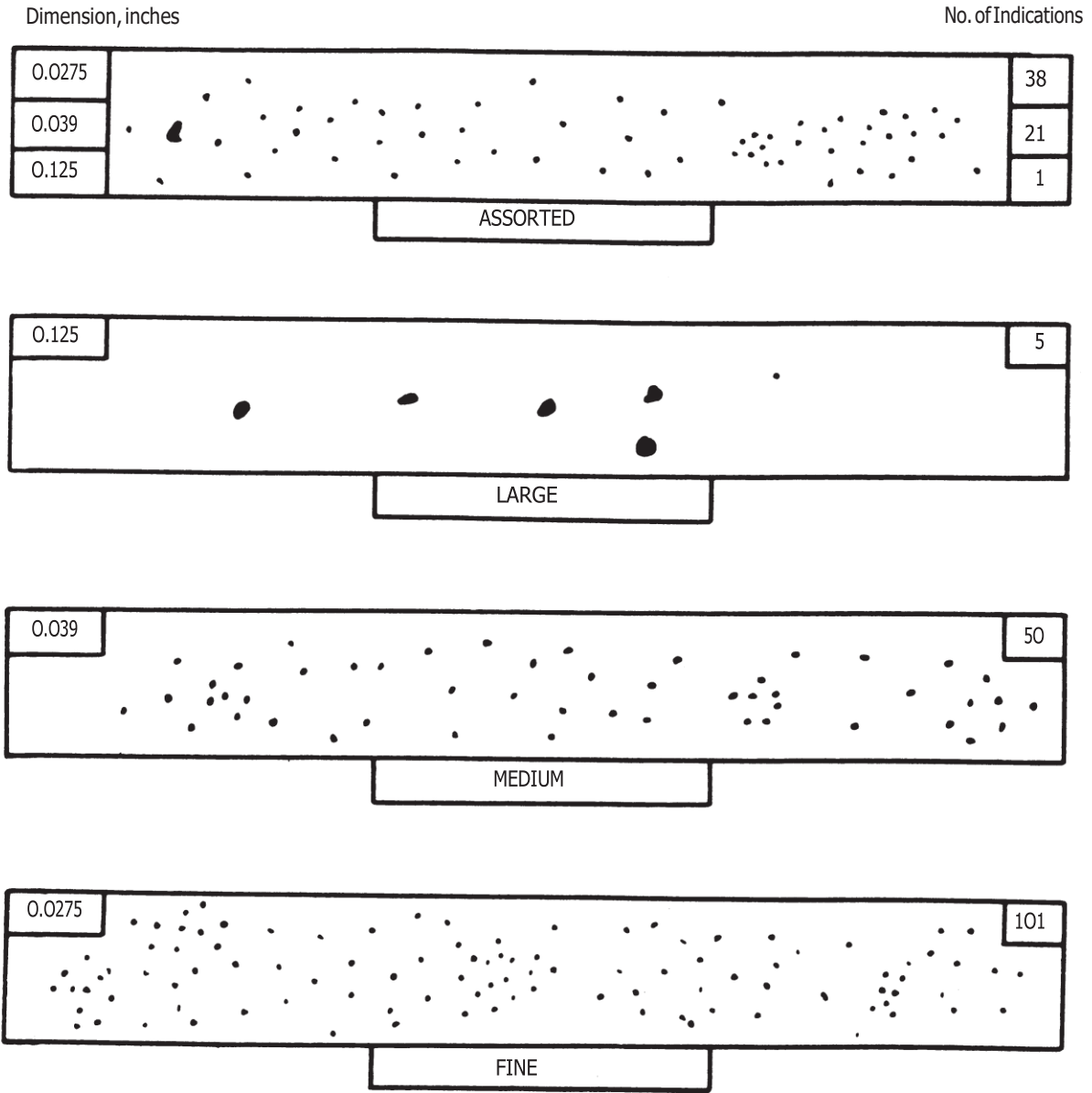
TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 152 MM LENGTH OF WELD.  
19.0 MM WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS 29.0 SQ. MM.

**Fig. W.17.1 Rounded indication charts**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

M-1002

APPENDIX W



TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 6-IN. LENGTH OF WELD.  
1-IN. WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS 0.060 SQ. IN.

**Fig. W.18 Rounded indication charts**

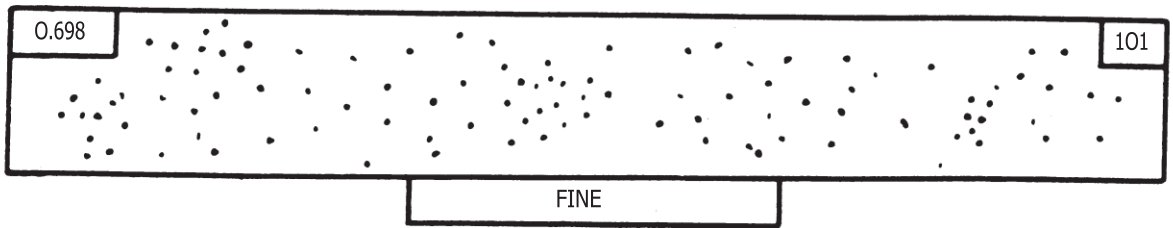
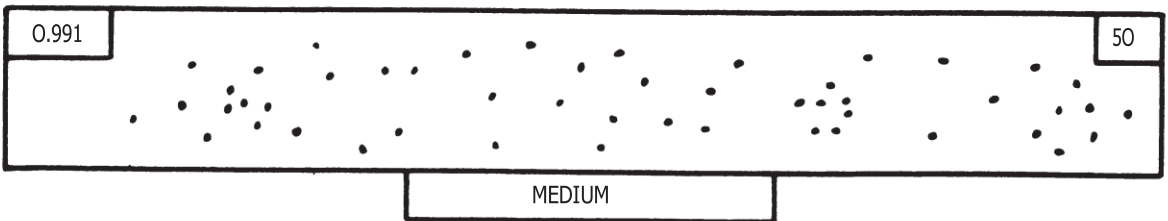
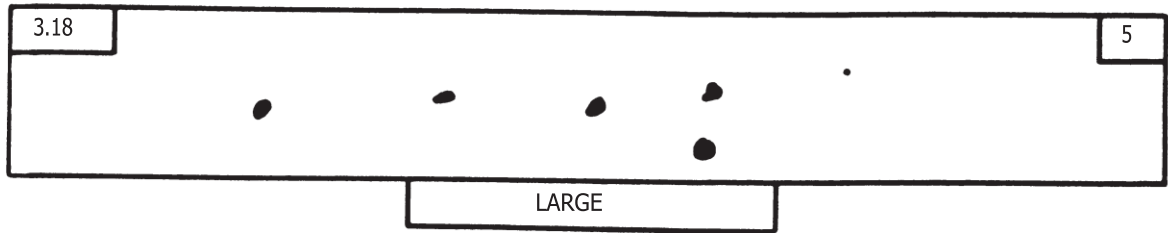
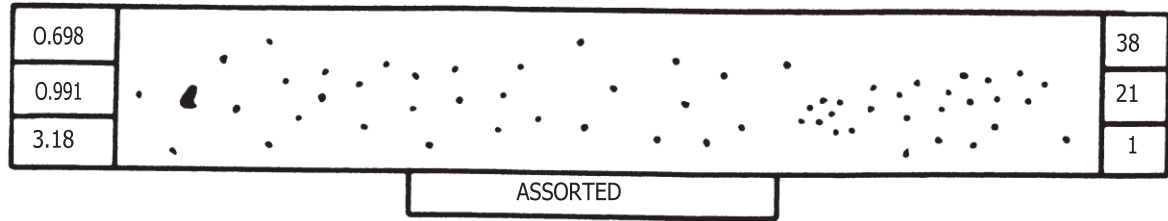
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Specifications for Tank Cars**

M-1002

APPENDIX W

Dimension, millimeters

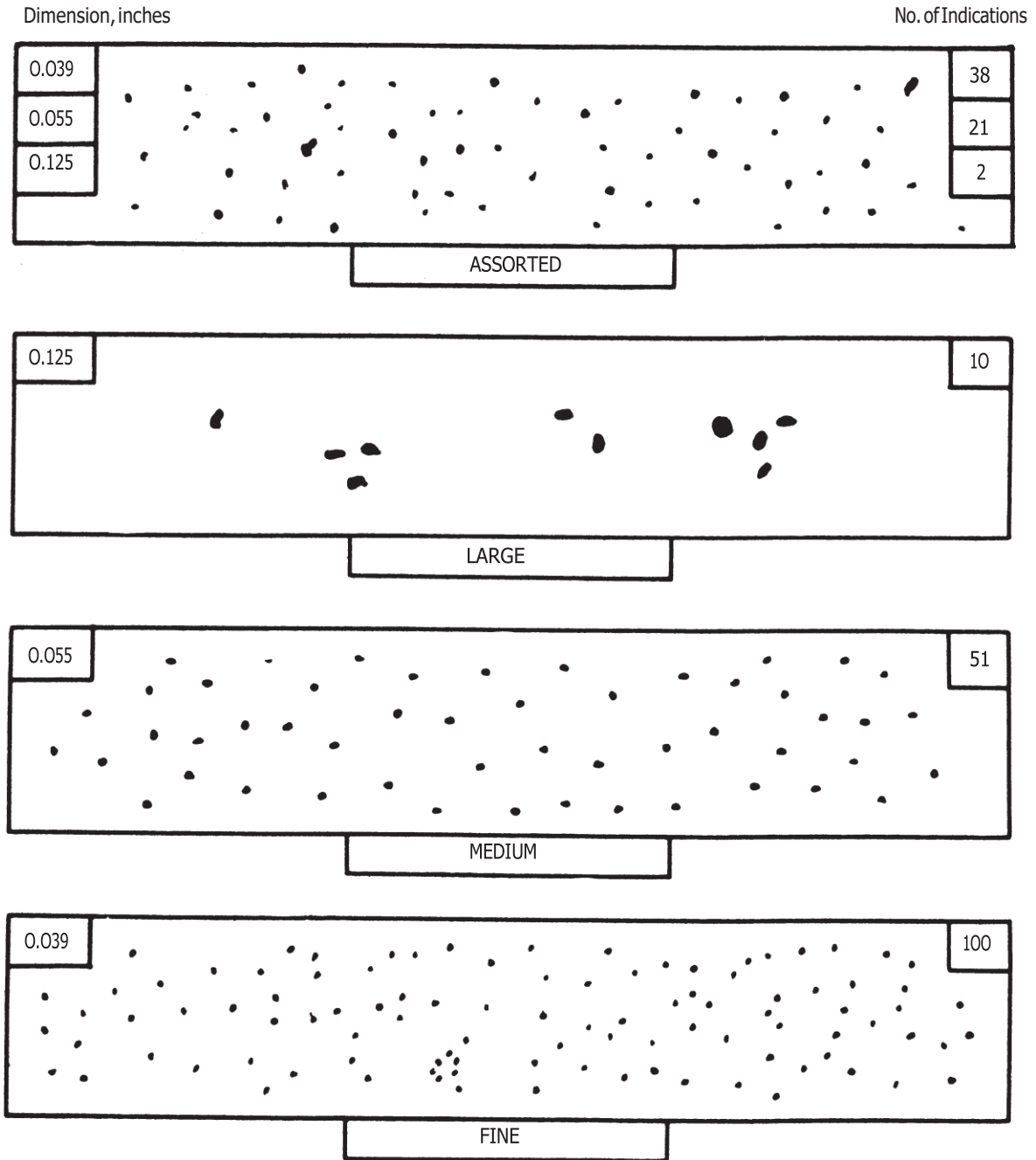
No. of Indications



TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 152 MM LENGTH OF WELD.  
25.4 MM WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS 38.7 SQ. MM.

**Fig. W.18.1 Rounded indication charts**

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Specifications for Tank Cars**



TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY SIX INCH LENGTH OF WELD. TWO  
INCH WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS .120 SQ. IN.

**Fig. W.19 Rounded indication charts**

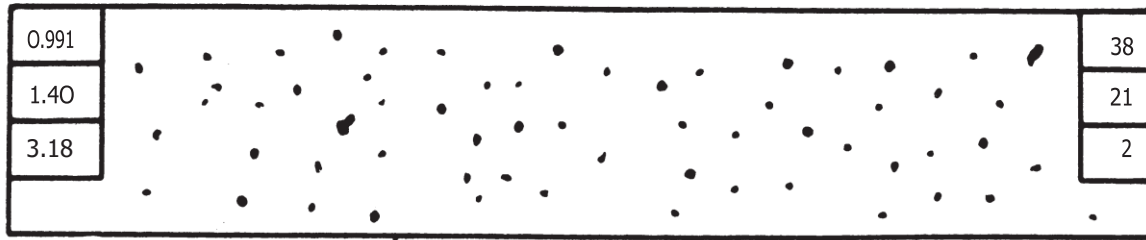
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Specifications for Tank Cars**

M-1002

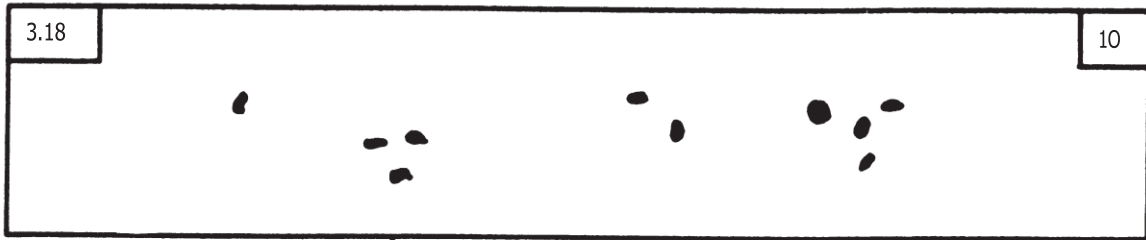
APPENDIX W

Dimension, millimeters

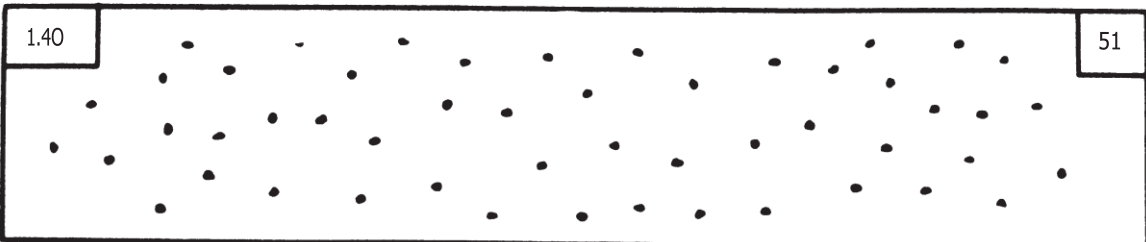
No. of Indications



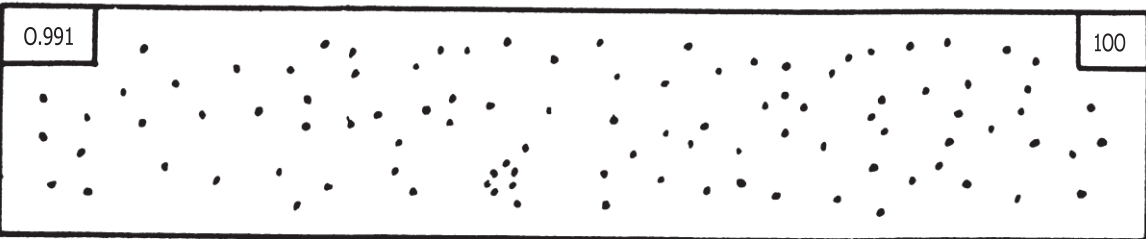
ASSORTED



LARGE



MEDIUM

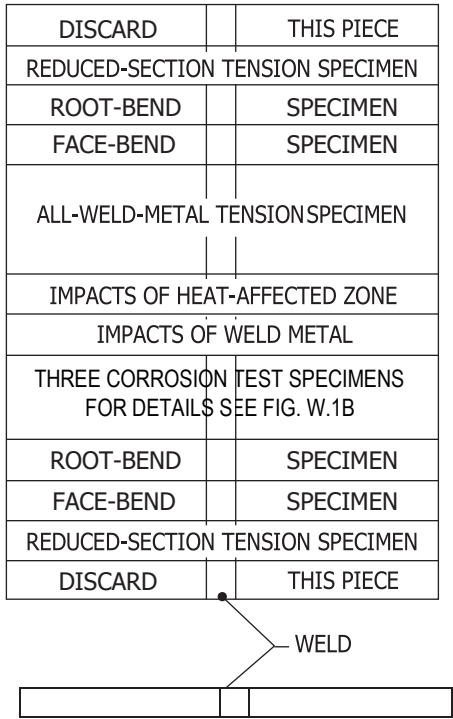


FINE

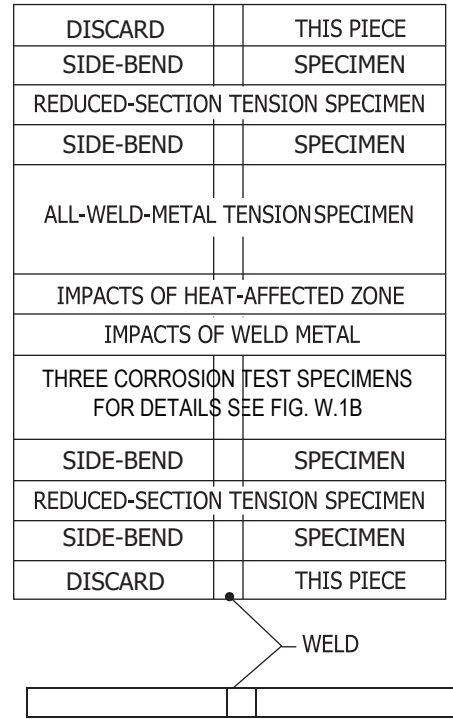
TYPICAL NUMBER AND SIZE PERMITTED IN  
ANY 152 MM LENGTH OF WELD.  
50.8 MM WELD THICKNESS.  
TOTAL INDICATION AREA PERMITTED IS 77.4 SQ. MM.

**Fig. W.19.1 Rounded indication charts**

**AAR Manual of Standards and Recommended Practices  
Specifications for Tank Cars**

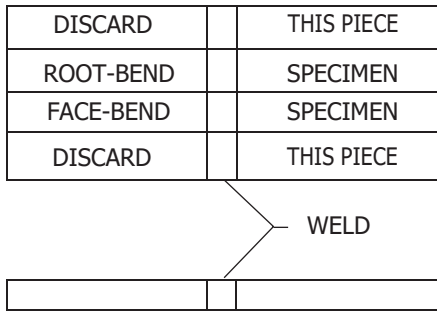


SKETCH A-FOR PLATES 1/16" TO 3/4" (1.59 TO 19.0) THICK

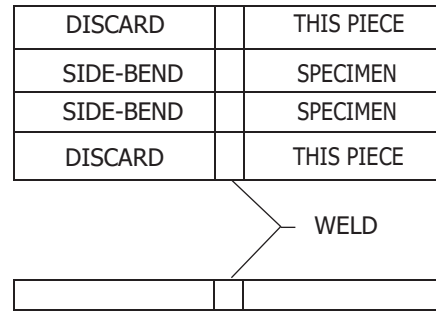


SKETCH B-FOR PLATES 3/8" (9.52) AND OVER THICK

WELDING PROCEDURE QUALIFICATION SPECIMEN



SKETCH C-FOR PLATES 1/16" TO 3/4" (1.59 TO 19.0) THICK



SKETCH D-FOR PLATES 3/8" (9.52) AND OVER THICK

WELDER PERFORMANCE QUALIFICATION SPECIMEN

**Fig. W.20 Order of removal of test specimens**

# AMERICAN WELDING SOCIETY

Basic Welding Symbols and Their Location Significance									
Location Significance	Fillet	Plug or Slot	Spot or Projection	Stud	Seam	Back or Backing	Surfacing	Flange Corner	Flange Edge
Arrow Side									
Other Side				Not Used			Not Used		
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
No Arrow Side or Other Side Significance	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used	Not Used
Location Significance	Groove							Scarf for Brazed Joint	
	SQUARE	V	Bevel	U	J	Flare-V	Flare-Bevel		
Arrow Side									
Other Side									
Both Sides									
No Arrow Side or Other Side Significance		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	
Supplementary Symbols					Location of Elements of a Welding Symbol				
Weld-All Around	Field Weld	Melt-Thru	Consumable Insert	Backing Spacer	Contour				
					Flush	Convex	Concave		
Basic Joints					Identification of Arrow Side and Other Side Joint				
Butt Joint		Corner Joint							
T-Joint		Lap Joint							
Edge Joint		Process Abbreviations							
						Where process abbreviations are to be included in the tail of the welding symbol, reference is made to Table 1, Designation of Welding and Allied Processes by Letters, of ANSI/AWS A2.4-92.			

**Fig. W.21 Welding symbols**

American Welding Society  
550 N.W. LeJeune Rd., P.O. Box 351043  
Miami, Florida 33135

# AMERICAN WELDING SOCIETY

Typical Welding Symbols		
<p><b>Double-Fillet Welding Symbol</b></p> <p>Weld size — 1/4 — Length — 6 — Pitch — 1/16 —</p> <p>Omission of length indicates that weld extends between abrupt changes in direction or as dimensioned</p>	<p><b>Chain Intermittent Fillet Welding Symbol</b></p> <p>Pitch (distance between centers) of increments — 5/16 — Size (length of leg) — 7/16 — Length of increments — 2-5, 2-6 —</p>	<p><b>Staggered Intermittent Fillet Welding Symbol</b></p> <p>Pitch (distance between centers) of increments — 3-5 — Size (length of leg) — 1/2 — Length of increments — 1/2 —</p>
<p><b>Plug Welding Symbol</b></p> <p>Included angle of countersink — 30° — Pitch (distance between centers) of welds — 4 — Size (diameter of hole at root) — 3/4 — Depth of filling in inches (omission indicates filling is complete) — 4 —</p>	<p><b>Back Welding Symbol</b></p> <p>Back weld — 1st operation — 2nd operation —</p>	<p><b>Backing Welding Symbol</b></p> <p>Backing weld — 1st operation — 2nd operation —</p>
<p><b>Spot Welding Symbol</b></p> <p>Size or strength — RSW 025 — Number of welds — (5) — Pitch — 4 — Process — RSW —</p>	<p><b>Stud Welding Symbol</b></p> <p>Size — 1/2 — Number of studs — (7) — Pitch — 6 —</p>	<p><b>Seam Welding Symbol</b></p> <p>Size or strength — 030 — Increment length — 3-9 — Pitch — 3-9 — Process — RSEW —</p>
<p><b>Square-Groove Welding Symbol</b></p> <p>Weld size — (3/16) — Root opening — 1/4 —</p>	<p><b>Single-V Groove Welding Symbol</b></p> <p>Depth of bevel — 1/2 — Root opening — 1/8 — Groove angle — 80° — Weld size — 1/2 —</p>	<p><b>Double-Bevel-Groove Welding Symbol</b></p> <p>Weld size — (1) — Root opening — (1-1/4) — Arrow points toward member to be prepared</p>
<p><b>Symbol with Backgouging</b></p> <p>Depth of bevel — 3/8 — Backgouge —</p>	<p><b>Flare-V-Groove Welding Symbol</b></p> <p>Weld size — (1/4) —</p>	<p><b>Flare-Bevel-Groove Welding Symbol</b></p> <p>Weld size — (1/4) —</p>
<p><b>Multiple Reference Lines</b></p> <p>1st operation on line nearest arrow — 2nd operation — 3rd operation —</p>	<p><b>Complete Penetration</b></p> <p>Indicates complete joint penetration regardless of type of weld or joint preparation — CJP —</p>	<p><b>Edge Flange Welding Symbol</b></p> <p>Radius — 3/64 + 1/16 — Weld size — 1/16 — Height above point of tangency —</p>
<p><b>Flash or Upset Welding Symbol</b></p> <p>Process reference — FW —</p>	<p><b>Melt-Thru Symbol</b></p> <p>Root reinforcement — 1/32 —</p>	<p><b>Joint with Backing</b></p> <p>'R' Indicates backing removed after welding</p>
<p><b>Joint with Spacer</b></p> <p>With modified groove weld symbol</p>	<p><b>Flush Contour Symbol</b></p>	<p><b>Convex Contour Symbol</b></p>
<p><b>Double bevel groove</b></p>		

\* It should be understood that these charts are intended only as shop aids. The only complete and official presentation of the standard welding symbols is in A2.4.

**Fig. W.21.1 Welding symbols**