AWS D8.1M:2007
An American National Standard

# Specification for Automotive Weld Quality—Resistance Spot Welding of Steel

American Welding Society

Approved American National Standard
ANSI

**AWS D8.1M:2007**
**An American National Standard**

**Approved by the**
**American National Standards Institute**
**January 12, 2007**

# Specification for Automotive Weld Quality— Resistance Spot Welding of Steel

**1st Edition**

Prepared by the
American Welding Society (AWS) D8 Committee on Automotive Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

## Abstract

This document contains both visual and measurable acceptance criteria for resistance spot welds in steels. The information contained herein may be used as an aid by designers, resistance welding equipment manufacturers, welded product producers, and others involved in the automotive industry and resistance spot welding of steels.

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# Foreword

This foreword is not part of AWS D8.1M:2007, *Specification for Automotive Weld Quality—Resistance Spot Welding of Steel*, but is included for informational purposes only.

This document has been prepared to establish acceptance criteria for resistance spot welds in automotive structures fabricated from steels including the Advanced High Strength Steels (AHSS). As a specification, the criteria and techniques contained are obligatory when cited as a normative reference on a drawing or in a contract.

This specification was prepared by the D8D Subcommittee on Automotive Resistance Spot Welding of the AWS D8 Committee on Automotive Welding in cooperation with the Auto/Steel Partnership Joining Technology Committee. This publication is issued under the auspices of the AWS D8 Committee on Automotive Welding.

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# Specification for Automotive Weld Quality—Resistance Spot Welding of Steel

## 1. Scope

This specification expresses an industry consensus of quality characteristics and metrics pertinent to resistance spot welds on automotive steels. The evaluation methods and inspection criteria specified herein can be used to evaluate the effectiveness of particular welding equipment and procedures used to weld a particular base material combination. The subject matter is considered to be realistic and tempered with the knowledge of what a resistance spot welding process is capable of accomplishing in a high volume production environment. The criteria and metrics are the same for all welds regardless of the service load and are intended to be applied in conditions typically encountered during manufacturing. Welds at variance from the stated weld quality criteria in this document can still have mechanical properties that satisfy product and design requirements. Any attempted application of this document, or the evaluation criteria contained herein, to other uses, such as post-crash weld quality assessment, may lead to an erroneous result.

This standard makes sole use of the International System of Units (SI).

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

## 2. Normative References

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

American Welding Society (AWS) standards:[1]

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

(2) AWS D8.9M, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*.

## 3. Terms and Definitions

The terms listed in AWS A3.0, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, shall apply to this document, except for those listed below. The terms listed below as used in various sections of this document require definition for correct interpretation. Most of these terms are not contained in AWS A3.0, or if they are listed, their definitions have been enhanced to clarify their use in this document.

For the purposes of this document, the following definitions apply:

**aspect ratio.** The ratio of the maximum dimension to the minimum dimension of the fused area.

**button.** The part of a spot weld which tears out during destructive testing of welded steel. It may include all or part of the nugget, the heat-affected zone (HAZ) and base metal. A hole is left in the mating sheet(s).

**button pull.** A fracture mode of a spot weld where separation occurs through the heat-affected zone (HAZ) of the weld, resulting in a button (see example in Figure 10).

**button size.** The average of the maximum and minimum dimensions of the button.

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

**fracture mode.** The appearance of the weld after destructive testing as categorized in Figures 10 through 17.

**fused area.** The area of the nugget at the faying surface (interface between the metals being joined). The fused area may result in button pull, partial thickness fracture, interfacial fracture, or combinations thereof.

**fusion zone.** The volume of fused base metal resulting from the welding process. The fusion zone is visible when a weld is cross-sectioned and suitably etched.

**governing metal thickness (GMT).** The metal gage in a stackup that determines the minimum acceptable weld size. The GMT for a two-sheet stackup is the metal thickness of the thinner of the two sheets. Generally, the GMT for a three-sheet stackup is the metal thickness of the second thickest sheet.

**heat-affected zone (HAZ).** The portion of base metal adjacent to the nugget whose mechanical properties or microstructure have been altered by the heat input from welding.

**interfacial fracture.** A fracture mode of a spot weld where all of the weld nugget separates through the plane of the weld at the faying surface. If less than approximately 20% of the mating sheet thickness is removed, the fracture is interfacial (see example in Figure 16).

**nugget.** The weld metal joining the work pieces, consisting of the fusion zone (solidified metal), but excluding the heat-affected zone.

**partial thickness fracture.** A fracture mode of a spot weld where a part of the weld nugget shows removal of parent metal by the weld from the mating sheet. This mode may or may not include some button pull. The portion removed must be at least approximately 20% of the mating sheet thickness, otherwise the fracture is interfacial. A cavity is left in the mating sheet (see example in Figure 12).

**weld size.** The average of the maximum and minimum dimensions of the fused area in destructive inspection or the nugget width in metallographic inspection.

# 4. Weld Process Control

Production-welded parts being joined by the resistance spot welding process have inherent variability of weld quality characteristics. Therefore, some tolerance must be established for the required quality so as to be consistent with the manufacturing process capabilities. The welding process must be controlled to meet or exceed the minimum weld quality level that meets the product requirements. Information and guidance pertaining to supplier requirements for process and product control are contained in the *Quality System Requirements, QS-9000 Third Edition* or in the latest edition of ISO/TS 16949, *Quality Systems — Automotive suppliers — Particular Requirements for the Application of ISO 9001:2000*, published by the Automotive Industry Action Group (AIAG).[2]

# 5. Spot Weld Acceptance Criteria

The intended use of this specification is to satisfy the needs of both shop floor and laboratory applications to define automotive weld quality. Not all inspection methods of this specification need to be applied simultaneously to determine weld quality. Rather, the test method(s) most appropriate for the application, as determined by an agreement between the customer and supplier, shall be considered adequate to define the weld quality for a specific application.

This specification is divided into four major areas, based on the method of inspection:

(1) Surface Inspection (see 5.1)

(2) Destructive Inspection

  (a) Metallographic (see 5.2)

  (b) Peel and Chisel (see 5.3)

  (c) Shear and Cross Tension (see 5.4)

Automotive welds are defined as having acceptable weld quality if they meet any one or more of these major areas as appropriately agreed upon.

For this specification, steels are classified according to minimum ultimate tensile strength as shown in Table 1.

### 5.1 Surface Inspection Criteria

**5.1.1 Edge Weld.** A spot weld area, as defined by the impression left by the electrodes, which is not fully contained within all original edges of the sheet metal is a discrepant weld (see Figure 1).

**5.1.2 Surface Cracks.** The acceptability of surface cracks, found when visually inspecting welds without a

[2] AIAG documents are published by the Automotive Industry Action Group, Dept. 77839, P.O. Box 77000, Detroit, MI 48277.

**Table 1**
**Classification of Steels for Resistance Spot Welding Purposes[a]**

| Group: | 1. Low Strength | 2. Intermediate Strength | 3. High Strength | 4. Ultra High Strength |
|---|---|---|---|---|
| Tensile Strength (MPa): | <350 | 350–500 | >500–800 | >800 |
| Typical Materials: | Mild 140YS/270TS<br>BH 180YS/300TS<br>BH 210YS/320TS<br>BH 240YS/340TS | BH 260YS/370TS<br>HSLA 280YS/350TS<br>HSLA 350YS/450TS<br>DP 300YS/500TS | DP 350YS/600TS<br>TRIP 350YS/600TS<br>DP 500YS/800TS<br>TRIP 500YS/800TS<br>CP 700YS/800TS | DP 700YS/1000TS<br>MS 950YS/1200TS<br>MS 1150YS/1400TS<br>MS 1250YS/1520TS<br>HS 950YS/1300TS |

[a] BH: Bake Hardenable, HSLA: High Strength Low Alloy, DP: Dual Phase, TRIP: Transformation Induced Plasticity, MS: Martensitic, CP: Complex Phase, YS: Yield Strength, TS: Tensile Strength.

Note: Steels with a minimum tensile strength above 500 MPa (Groups 3 and 4) are generally considered Advanced High Strength Steels (AHSS).

*Source:* International Iron and Steel Institute (IISI), *Advanced High Strength Steel (AHSS) Application Guidelines*, September 2006.

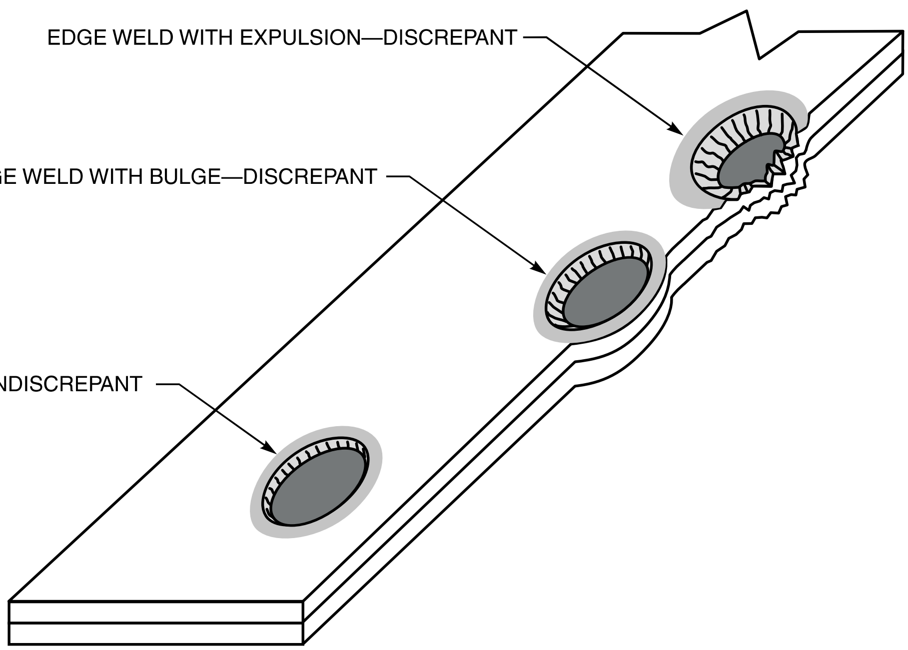



**Figure 1—Examples of Edge Welds**

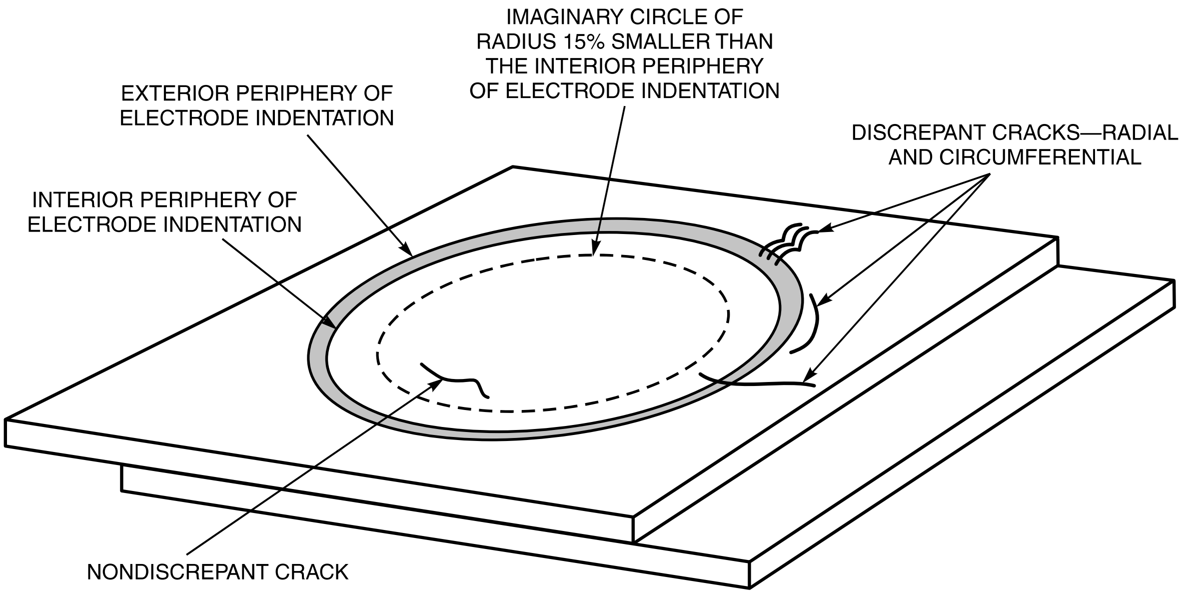
magnification device, depends on the steels being welded and the position of the cracks as shown in Figure 2.

**5.1.3 Holes.** A weld is discrepant when, upon visual inspection without a magnification device, any opening contained within the electrode impression is found extending through the stackup.

**5.1.4 Indentation.** Indentation is the ratio of the amount of weld depression to the pre-welded sheet thickness, expressed as a percentage. Indentation should be less than 30% of the thickness of each outside sheet of the welded joint (see Figure 3). Care must be taken during measurement if distortion is present. Distortion must not add to the value of the indentation.

### 5.2 Destructive Inspection—Metallographic Criteria

**5.2.1 Nugget Width.** An acceptable weld has a nugget width greater than or equal to the minimum weld size shown in Table 2 unless specified otherwise on the controlling engineering documents. The values in this table




**Discrepant Conditions:**

*Groups 1 and 2:*

1. Spot welds with surface cracks in the area defined by the outside 15% of the linear distance between the interior periphery line and the center of electrode impression (see drawings above).
2. Spot welds with surface cracks adjacent to the periphery of the electrode impression (see drawings above).

*Groups 3 and 4:*

When at least one of the steels in the stackup belongs to Group 3 or 4, no surface cracks are allowed unless specifically approved by the customer.

**Figure 2—Surface Cracks**

are based on a minimum of $4 \times \sqrt{t}$, where t is the Governing Metal Thickness. An illustration of nugget width is shown in Figure 4. Information on weld specimen preparation for nugget width measurement is contained in AWS D8.9M, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*. When determining the nugget width of a weld that has already been destructively tested, the cross section must be taken through what appears to be the minimum dimension of the fused area.

**5.2.2 Penetration.** Penetration is the ratio of the nugget's maximum depth of fusion to the pre-welded sheet thickness, expressed as a percentage. Penetration must exceed 20% of the pre-welded sheet thickness into each sheet of the weldment (see Figure 5). Note that 100% penetration is undesirable and may result in other discrepancies.

**5.2.3 Porosity.** Pores, cavities or voids observed in a weld cross section that meet any one of the criteria listed in Figure 6 are considered discrepant. Examination shall occur at a magnification of 10X.

**5.2.4 Internal Cracks.** Cracks observed in a weld cross section are considered internal cracks. Welds with cracks located in the nugget or HAZ that meet any one of the criteria listed in Figure 7 are considered discrepant. Examination shall occur at a magnification of 10X.

**5.3 Destructive Inspection—Peel and Chisel Criteria.** Destructive testing will result in different fracture modes depending on the material thickness, material composition, steel strength, part geometry or the type and rates of loading. The basic fracture modes are interfacial fracture, partial thickness fracture, button pull, or combinations thereof.

Peel and chisel testing of resistance spot welds in Advanced High Strength Steel (AHSS) may produce fracture through the weld, resulting in interfacial or partial thickness fractures. These fractures become more common with increasing sheet thickness and base material strength. Judgment of weld quality should

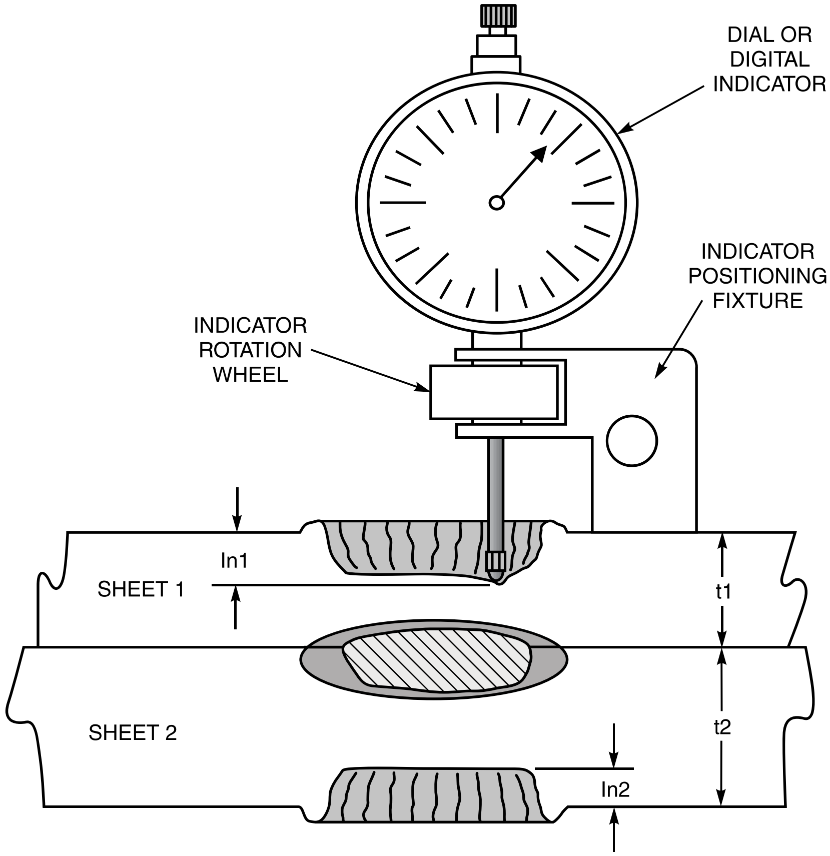



**Figure 3—Indentation Measurement**

**Table 2**
**Minimum Acceptable Weld Size[a, b]**

| Governing Metal Thickness (mm) | Weld Size (mm) |
|---|---|
| 0.60–0.79 | 3.5 |
| 0.80–0.99 | 4.0 |
| 1.00–1.29 | 4.5 |
| 1.30–1.59 | 5.0 |
| 1.60–1.89 | 5.5 |
| 1.90–2.29 | 6.0 |
| 2.30–2.69 | 6.5 |
| 2.70–3.09 | 7.0 |
| 3.10–3.59 | 7.5 |

[a] This table does not cover more than three-thickness welding.
[b] This table applies whether determined by destructive or metallographic inspection.

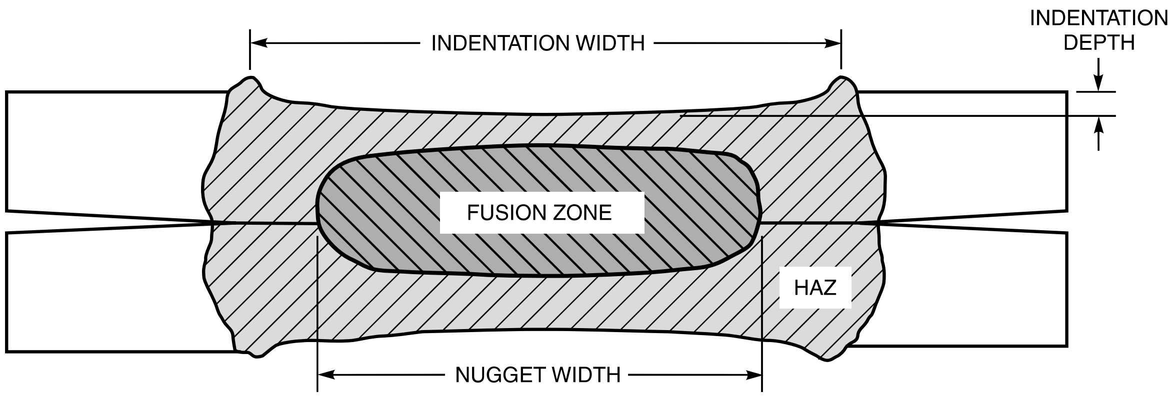



**Figure 4—Attributes of a Spot Weld Measured from a Cross Section**

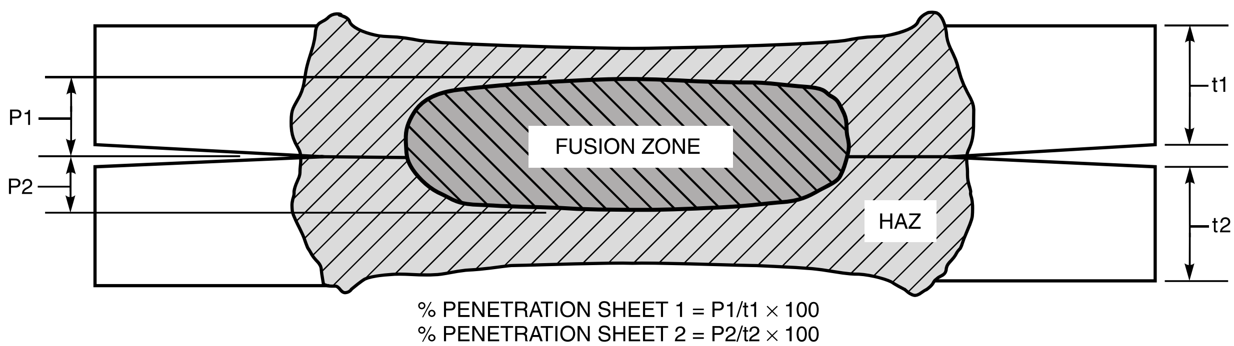
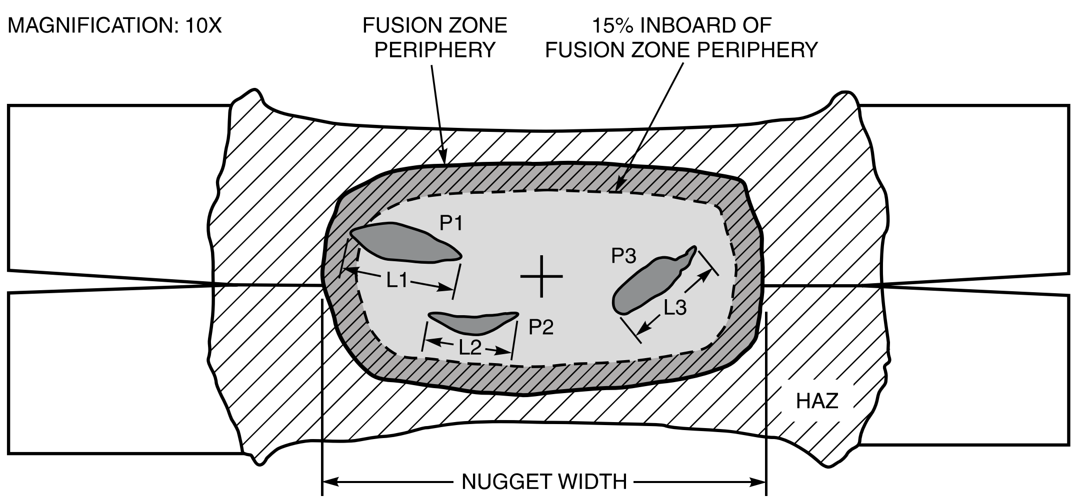



**Figure 5—Penetration Measurement**

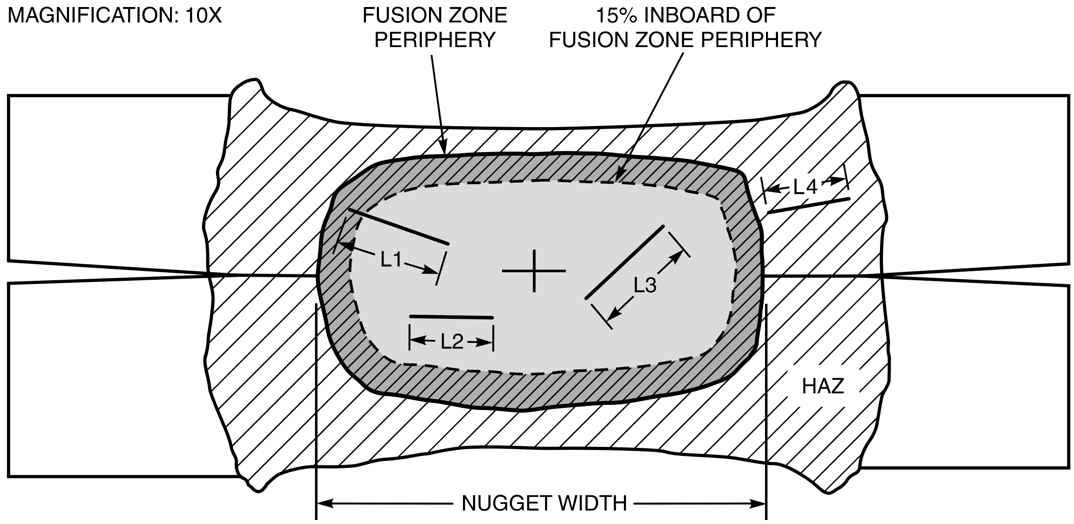



**Discrepant Conditions:**

1. Sum of all areas (e.g., Area P1 + Area P2 + Area P3) ≥ 15% of Nugget Area.
2. Sum of all lengths (e.g., L1 + L2 + L3) ≥ 25% of Nugget Width.
3. Pores or cavities in area defined in the outside 15% of the linear distance between the fusion zone periphery and its center (e.g., Area P1).

Note: Higher magnifications may be used to aid area or length measurements.

**Figure 6—Example of Discrepant Pores and Cavities**




**Discrepant Conditions:**

1. Sum of all lengths in the fusion zone (e.g., L1 + L2 + L3) ≥ 25% of Nugget Width.
2. Cracks in the HAZ or nugget area defined by the outside 15% of the linear distance between the fusion zone periphery and its center (e.g., L1 and L4). An exception can be considered for those that would have been deemed acceptable by surface inspection and do not extend into the fusion zone.

**Figure 7—Example of Discrepant Internal Cracks**

incorporate the amount of deformation of the metal adjacent to the weld and the level of effort required to produce fracture. Note that low ductility or thick gage steels might not exhibit deformation.

Nondestructive chisel or prybar testing is commonly used in production environments to check for fusion between welded steels without producing permanent damage to the components. However, because of the inherent stiffness of AHSS sheets, prybar testing on AHSS spot welded panels will deform the panel permanently and may inadvertently promote weld metal fracture. Therefore, prybar testing is not acceptable for AHSS unless specifically approved by authorized personnel.

**5.3.1 Weld Size.** In destructive testing, weld size is determined by measuring the known fused area. In most instances this means measuring only button and partial thickness fractures (i.e., material protruding from one of the previously welded sheets). Interfacial fractures can be included in the measurement only when proven to be part of a nugget by other means such as metallographic inspection.

The weld size is calculated as the average of the maximum dimension and the minimum dimension, which may not always be 90° from each other. These measurements are typically made with calipers. Irregular shaped welds are measured as shown in Figures 8 and 9. All welds must not exceed an aspect ratio of 2 to 1. The tail that might be formed on a button by destructively tearing the two sheets apart shall not be included in the button measurement.

An acceptable weld size is defined by Table 2. As with nugget width, the governing metal thickness (GMT) determines the minimum acceptable weld size unless specified otherwise in the controlling engineering documents.

**5.3.2 Fracture Mode.** Eight combinations of fracture modes are described in Figures 10 through 17, where their weld quality acceptance criteria are also summarized. When interpretation of weld size is disputed, metallographic inspection must be used to measure nugget width. When determining the nugget width of a weld that has already been destructively tested, the cross section must be taken through what appears to be the minimum dimension of the fused area.

**5.4 Destructive Inspection—Shear and Cross Tension Criteria.** The mechanical properties to be considered when evaluating weld quality are weld strength and weld energy. Weld mechanical performance of Advanced High Strength Steels (AHSS) may depend upon the

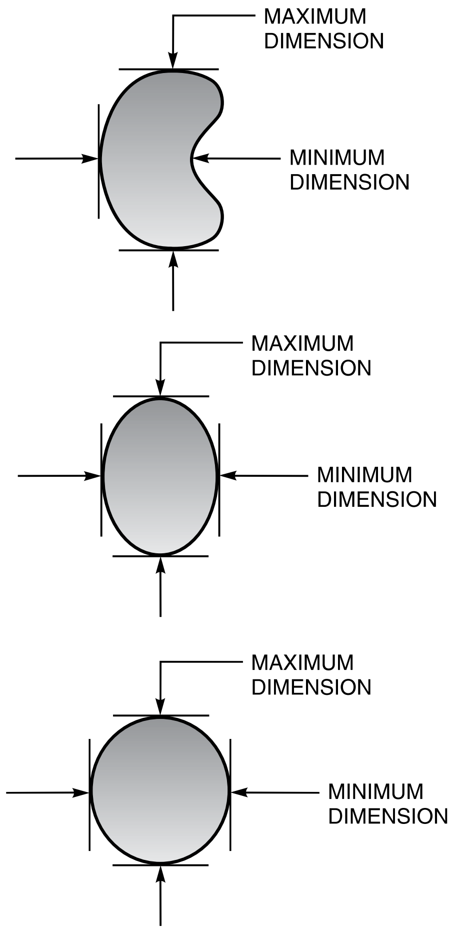



**Figure 8—Measurement Method**

loading mode, loading rate and degree of constraint. The strength of a weld is quantified by the peak load achieved during shear or cross tension testing. Weld strength shall be recorded using the test methods described in 5.4.3. While only values for minimum strength are used to quantitatively describe weld quality in this specification, weld energy values may be qualitatively considered.

Both shear and cross tension strength are measures of weld mechanical strength. Equations for these tests are used to describe the minimum expected values for steels in International Iron and Steel Institute (IISI) Steel Groups 2, 3, and 4 from Table 1. Welds with strengths below those computed by the equations are considered discrepant. The values determined by these equations must come from weld specimen designs described in 5.4.3. The equations for each test were determined from comparing formulas and data from other industry specifications, corporate research, and open literature. The equations are applicable to welds between two sheets of the same grade and gauge. They are applicable to sheet thicknesses between 0.6 mm and 3.0 mm, with weld size assumed to be at minimum per Table 2.

**5.4.1 Minimum Shear Tension Strength.** The minimum shear tension strength is computed using Equation (1).

$$ST = \frac{(-6.36E^{-7} \times S^2 + 6.58E^{-4} \times S + 1.674) \times S \times 4 \times t^{1.5}}{1000}$$

Equation (1)

where:

$ST$ = Shear Tension Strength (kN)
$S$ = Base Metal Tensile Strength (MPa)
$t$ = Material Thickness (mm)

Graphs of Equation (1) for representative steels in Groups 2 through 4 are given in Figures 18 through 20. Equation (1) should be computed for each specific weld under consideration.

**5.4.2 Minimum Cross Tension Strength.** The minimum cross tension strength is computed using Equation (2). Cross tension strength has not been conclusively found to be a function of base metal strength. This equation represents a lower bound for all material strengths as a function of material thickness.

$$CT = 1.25 \times t^{2.2}$$ Equation (2)

where:

$CT$ = Cross Tension Strength (kN)
$t$ = Material Thickness (mm)

A graph of Equation (2) for steels in Groups 2 through 4 is given in Figure 21. Equation (2) should be computed for each specific weld under consideration.

**5.4.3 Test Methods**

**5.4.3.1 Shear Tension Test.** A shear tension test is a quasi-static test performed by pulling lap-joined specimens on a tensile testing machine. The procedure documented in AWS D8.9M shall be followed. The sample geometry is shown in Figure 22 with coupon sizes listed in Table 3. The metrics that can be monitored include the peak value of load (peak load), displacement up to the peak load, energy defined by the area under the load-displacement curve up to the peak load, and fracture mode. These metrics are defined further in Figure 23. Fracture modes are characterized in Figures 10 through 17. The equation for determining minimum tensile strength values is given in 5.4.1.

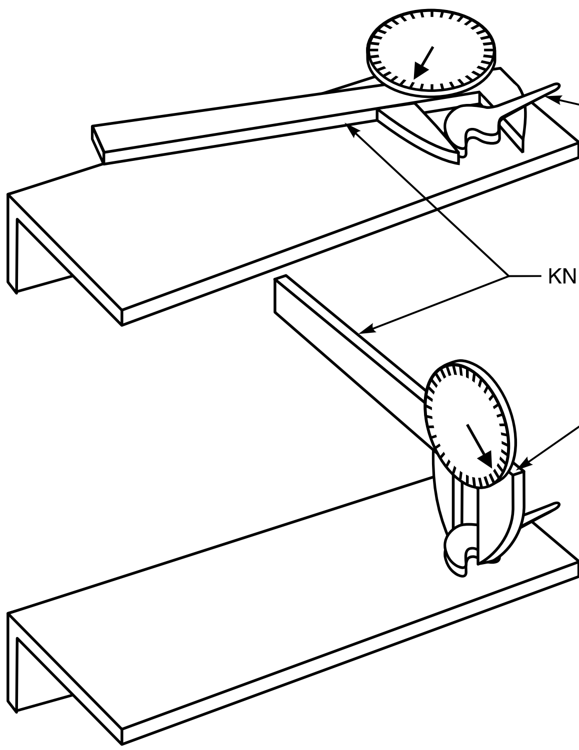
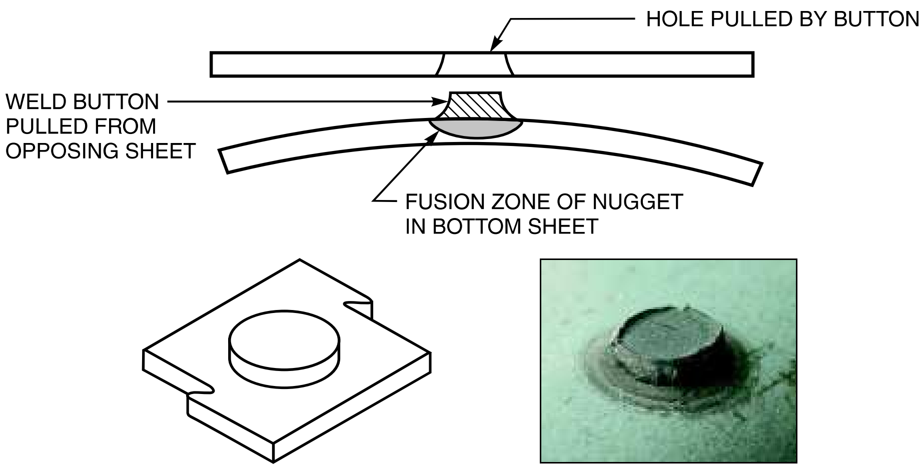


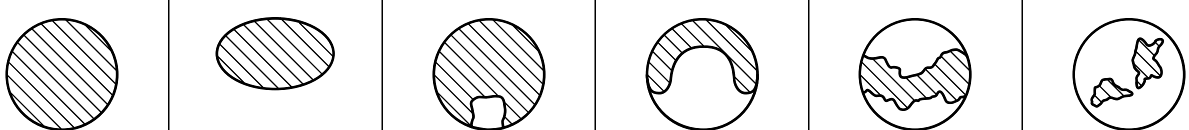

**Figure 9—Example of Measuring a Crescent Button**

**5.4.3.2 Cross Tension Test.** A cross tension test is a quasi-static test performed by pulling two coupons that have been spot welded together perpendicular to each other on a tensile testing machine. The procedure documented in AWS D8.9M shall be followed. The sample geometry is shown in Figure 24 with coupon sizes listed in Table 4. The metrics that can be monitored include the peak value of load (peak load), displacement up to the peak load, energy defined by the area under the load-displacement curve up to the peak load, and fracture mode. These metrics are defined further in Figure 23. Fracture modes are characterized in Figures 10 through 17. The equation for determining minimum cross tension values is given in 5.4.2.




WELD FRACTURE PLAN VIEW—BOTTOM SHEET
*(Some may not appear as in side view)*

| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|---|---|---|---|---|---|



Accept if the indicated Notes are satisfied (independent of the loading method):

| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|---|---|---|---|---|---|
| a | a + b | a | a + b | a + b | Discrepant |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

Weld Fracture Plan View Shading Area Legend

| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|---|---|---|---|

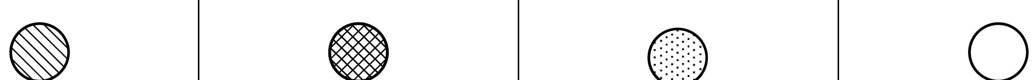
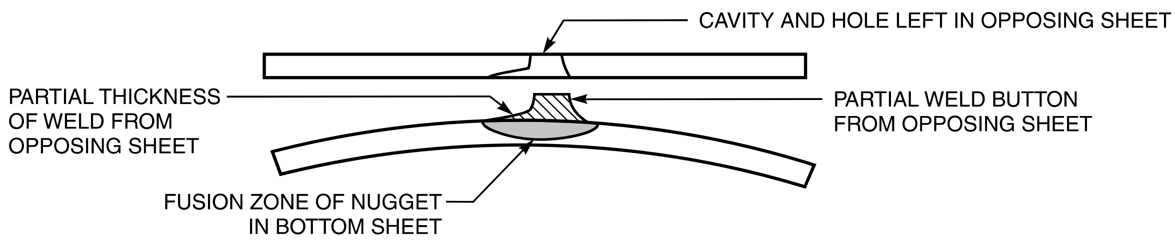
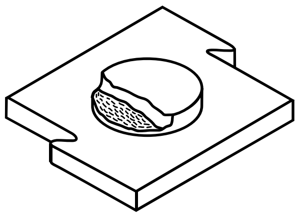
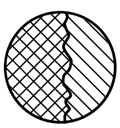
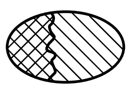
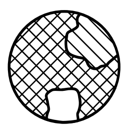
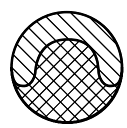
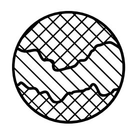
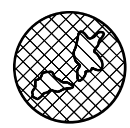


**Figure 10—Fracture Mode 1—Button Pull**



WELD FRACTURE PLAN VIEW—BOTTOM SHEET
*(Some may not appear as in side view)*

| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + c | a + b + c | a + c | a + c | a + c | a + c |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

Weld Fracture Plan View Shading Area Legend

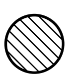
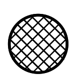
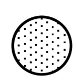
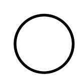
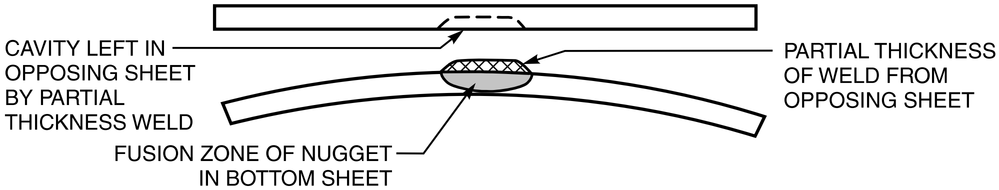
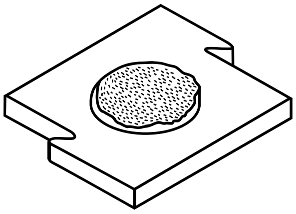
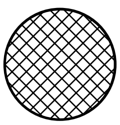
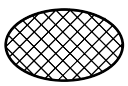
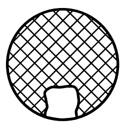
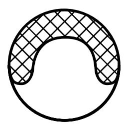
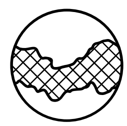
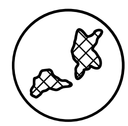
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|---|---|---|---|
|  |  |  |  |

**Figure 11—Fracture Mode 2—Partial Thickness Fracture with Button Pull**



| WELD FRACTURE PLAN VIEW—BOTTOM SHEET<br>*(Some may not appear as in side view)* | | | | | |
|---|---|---|---|---|---|
| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + c | a + b + c | a + c | a + b + c | a + b + c | Discrepant |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

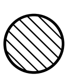
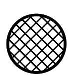
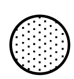
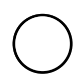
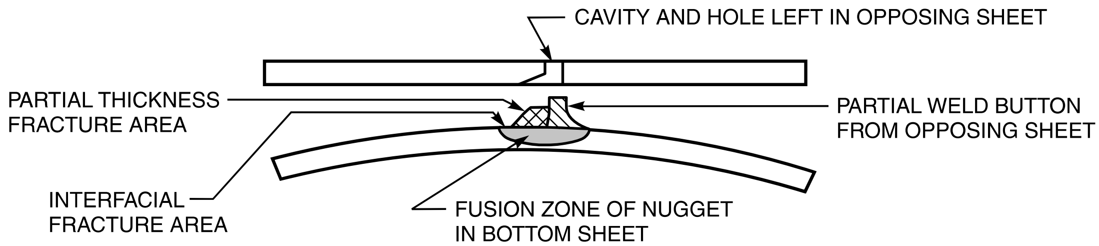
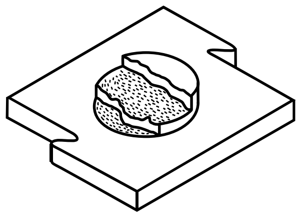
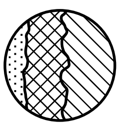
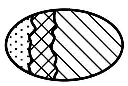
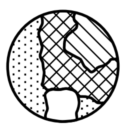
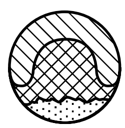
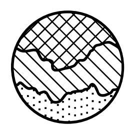
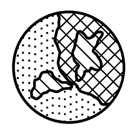
| Weld Fracture Plan View Shading Area Legend | | | |
|---|---|---|---|
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|  |  |  |  |

**Figure 12—Fracture Mode 3—Partial Thickness Fracture**



| WELD FRACTURE PLAN VIEW—BOTTOM SHEET<br>*(Some may not appear as in side view)* | | | | | |
|---|---|---|---|---|---|
| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/<br>Fused Area | Multiple Button/<br>Fused Area |
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + b + c | a + b + c | a + b + c | a + b + c | a + b + c | a + b + c |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

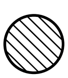
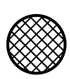
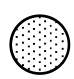
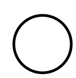
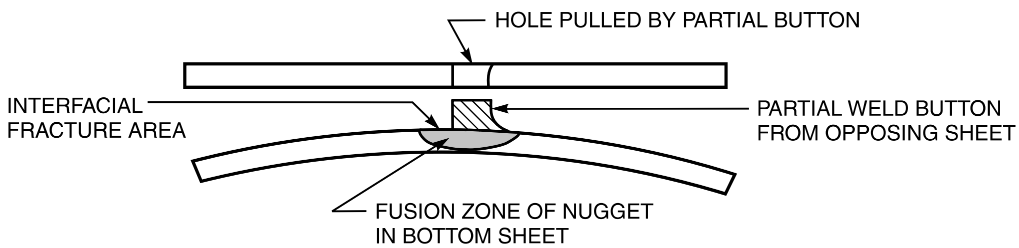
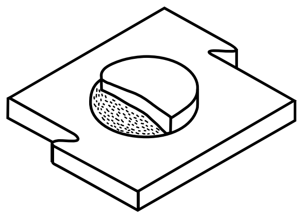
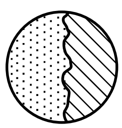
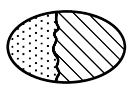
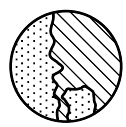
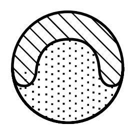
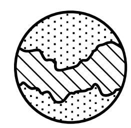
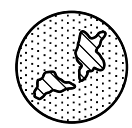
| Weld Fracture Plan View Shading Area Legend | | | |
|---|---|---|---|
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|  |  |  |  |

**Figure 13—Fracture Mode 4—Interfacial Fracture with Button Pull and Partial Thickness Fracture**



| WELD FRACTURE PLAN VIEW—BOTTOM SHEET<br>*(Some may not appear as in side view)* | | | | | |
|---|---|---|---|---|---|
| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/<br>Fused Area | Multiple Button/<br>Fused Area |
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + b + c | a + b + c | a + b + c | a + b + c | a + b + c | a + b + c |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

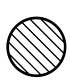
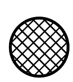
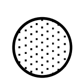
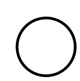
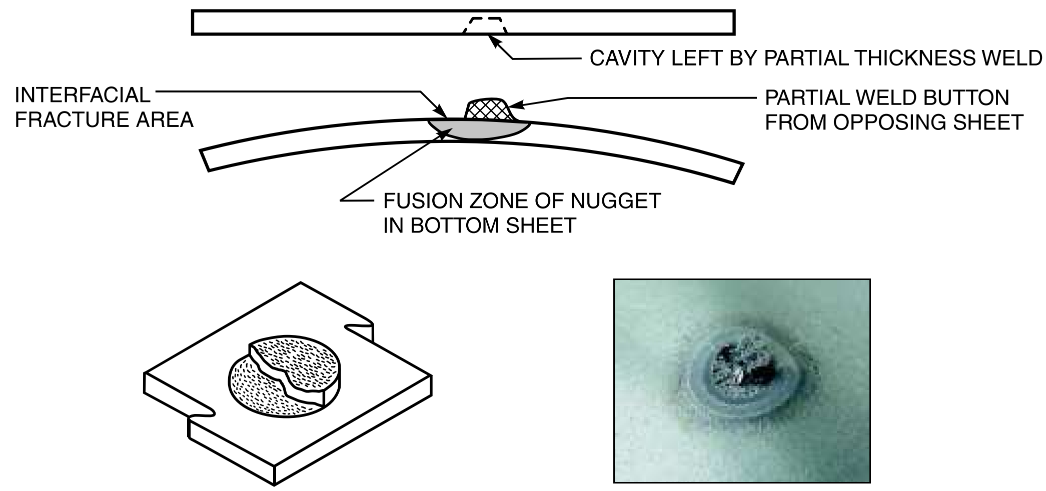
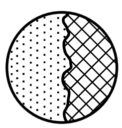
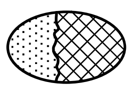
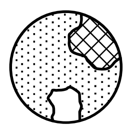
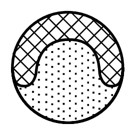
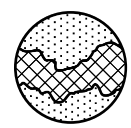
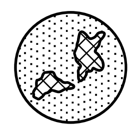
| Weld Fracture Plan View Shading Area Legend | | | |
|---|---|---|---|
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|  |  |  |  |

**Figure 14—Fracture Mode 5—Interfacial Fracture with Button Pull**




WELD FRACTURE PLAN VIEW—BOTTOM SHEET
*(Some may not appear as in side view)*

| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|---|---|---|---|---|---|
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + b + c | a + b + c | a + b + c | a + b + c | a + b + c | a + b + c |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

Weld Fracture Plan View Shading Area Legend

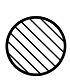
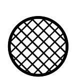
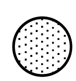
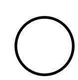
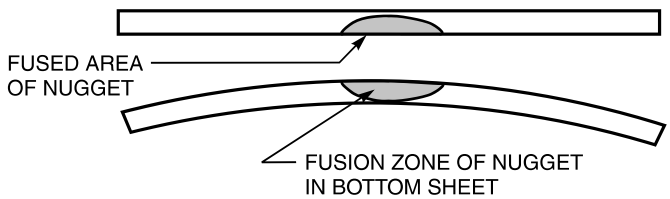
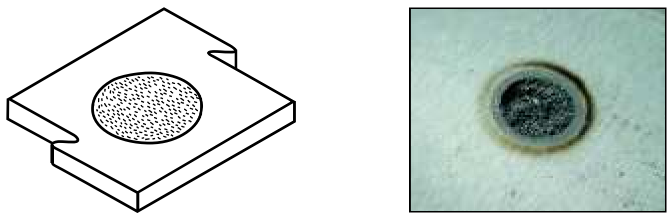
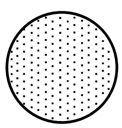
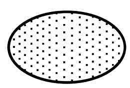
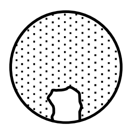
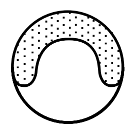
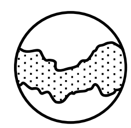
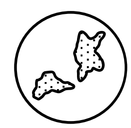
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|---|---|---|---|
|  |  |  |  |

**Figure 15—Fracture Mode 6—Interfacial Fracture with Partial Thickness Fracture**



| WELD FRACTURE PLAN VIEW—BOTTOM SHEET<br>*(Some may not appear as in side view)* | | | | | |
|---|---|---|---|---|---|
| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/<br>Fused Area | Multiple Button/<br>Fused Area |
|  |  |  |  |  |  |
| Accept if the indicated Notes are satisfied (independent of the loading method): | | | | | |
| a + c | a + b + c | a + c | a + b + c | a + b + c | Discrepant |

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

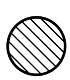
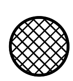
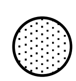
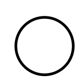
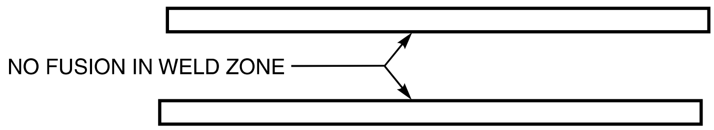
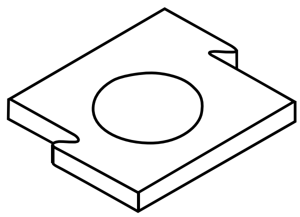
| Weld Fracture Plan View Shading Area Legend | | | |
|---|---|---|---|
| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|  |  |  |  |

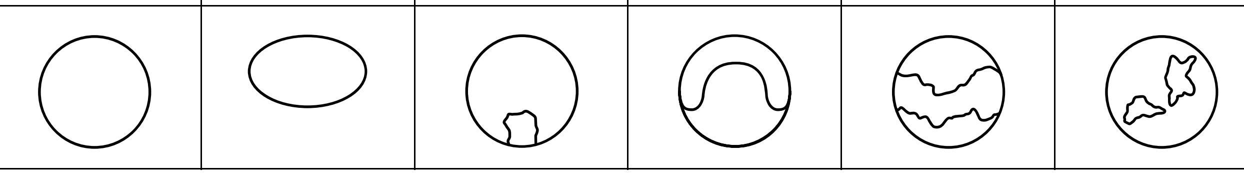
**Figure 16—Fracture Mode 7—Interfacial Fracture**



WELD FRACTURE PLAN VIEW—BOTTOM SHEET
*(Some may not appear as in side view)*

| Round | Oval | Hollow Area | Crescent Shape | Irregular Button/ Fused Area | Multiple Button/ Fused Area |
|---|---|---|---|---|---|



Accept if the indicated Notes are satisfied (independent of the loading method):

| d | d | d | d | d | d |
|---|---|---|---|---|---|

Notes:

a. Average of the maximum and minimum dimension of the known fused area (see 5.3.1) must be greater than or equal to the minimum weld size specified in Table 2.

b. Aspect ratio of maximum dimension to the minimum dimension is less than or equal to 2 to 1.

c. Evidence of metal deformation due to the existence of a weld. Note that low ductility or thick gage steels might not exhibit deformation.

d. Metallographic inspection only. Cross section must be taken through what appears to be the minimum dimension of the fused area.

Weld Fracture Plan View Shading Area Legend

| Through Sheet Button | Partial Thickness Fracture | Interfacial Fracture | No Fusion |
|---|---|---|---|

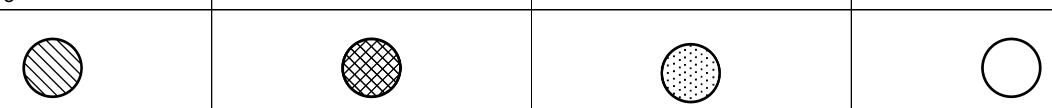


**Figure 17—Fracture Mode 8—No Fusion**

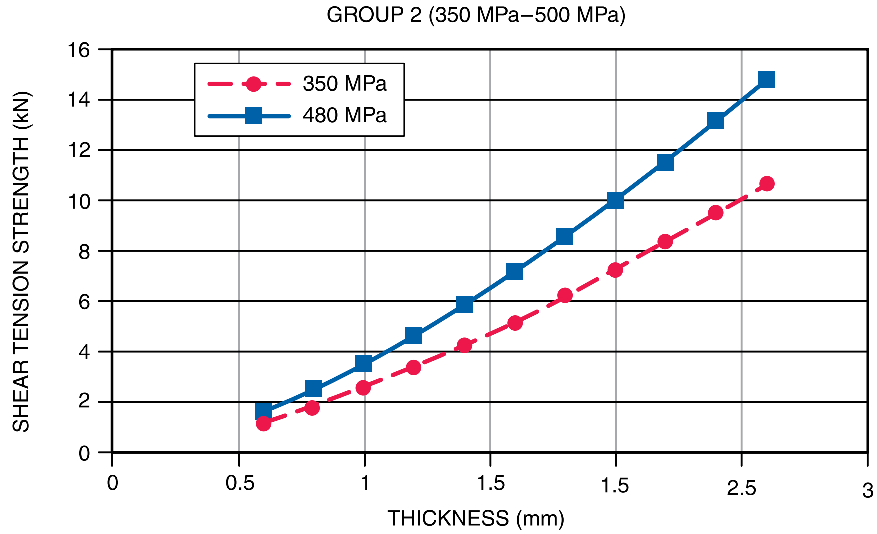



**Figure 18—Representative Minimum Shear Tension Strength Values for Group 2 Steels**

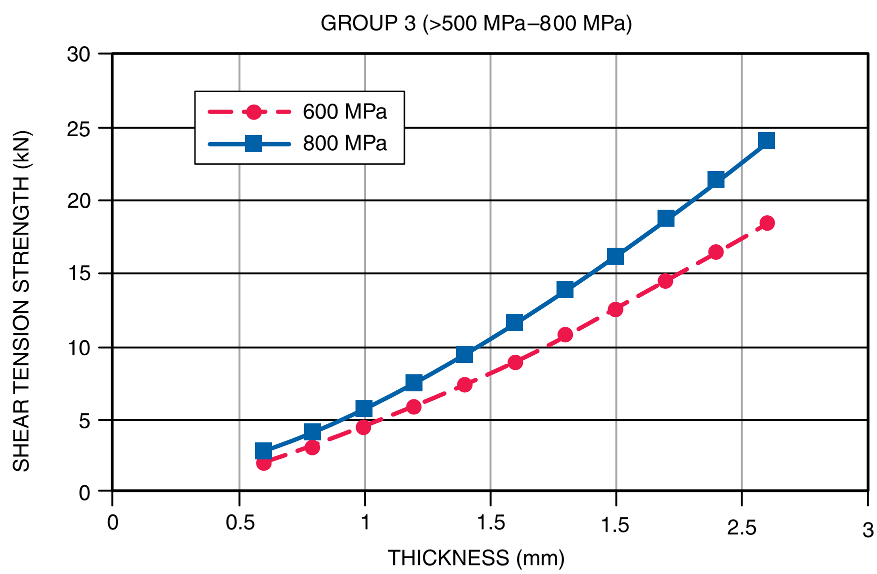



**Figure 19—Representative Minimum Shear Tension Strength Values for Group 3 Steels**

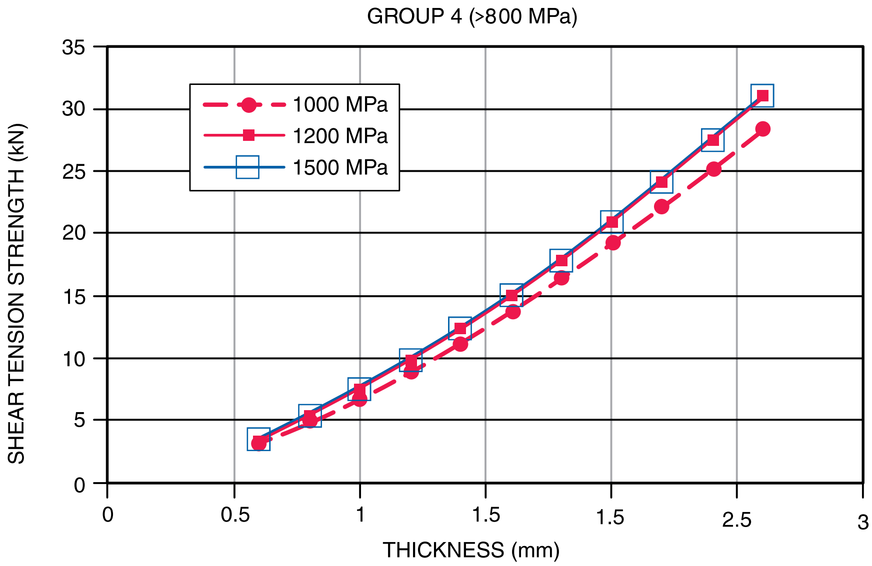



**Figure 20—Representative Minimum Shear Tension Strength Values for Group 4 Steels**

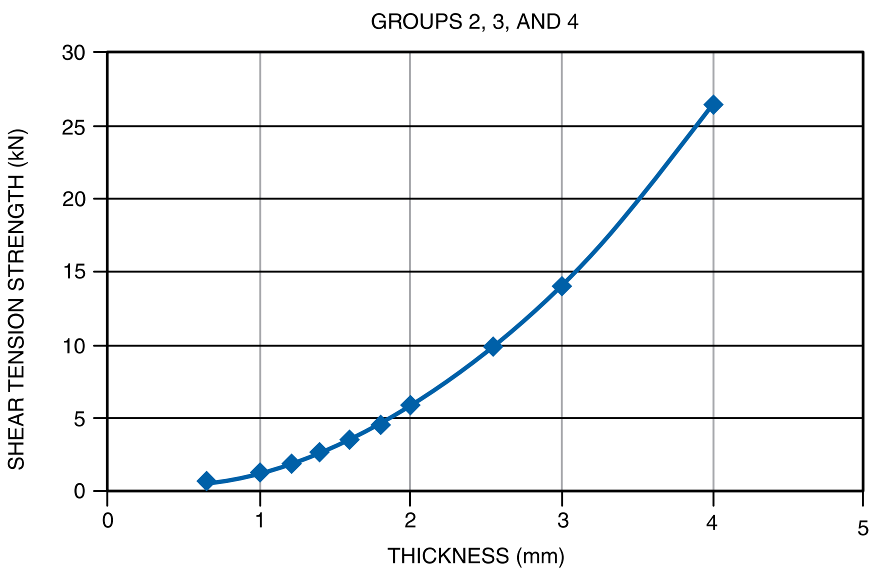



**Figure 21—Minimum Cross Tension Strength Values for Group 2, 3, and 4 Steels**

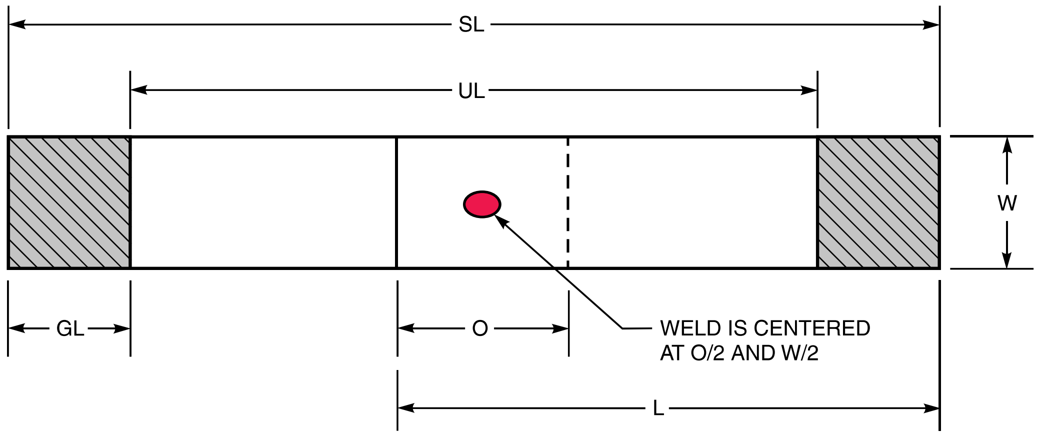



**Figure 22—Schematic for Shear Tension Samples**

**Table 3**
**Shear Tension Sample Dimensions**

| Sheet Thickness (mm) | Coupon Length L[a] (mm) | Coupon Width W[b] (mm) | Overlap O[b] (mm) | Sample Length SL[a] (mm) | Unclamped Length UL[b] (mm) | Gripped Length GL[a] (mm) |
|---|---|---|---|---|---|---|
| 0.60–1.29 | 105 | 45 | 35 | 175 | 95 | 40 |
| 1.30–3.00 | 138 | 60 | 45 | 230 | 105 | 62.5 |

[a] Lengths may be increased to accommodate gripping fixtures.
[b] Tolerance: ± 1.0 mm.

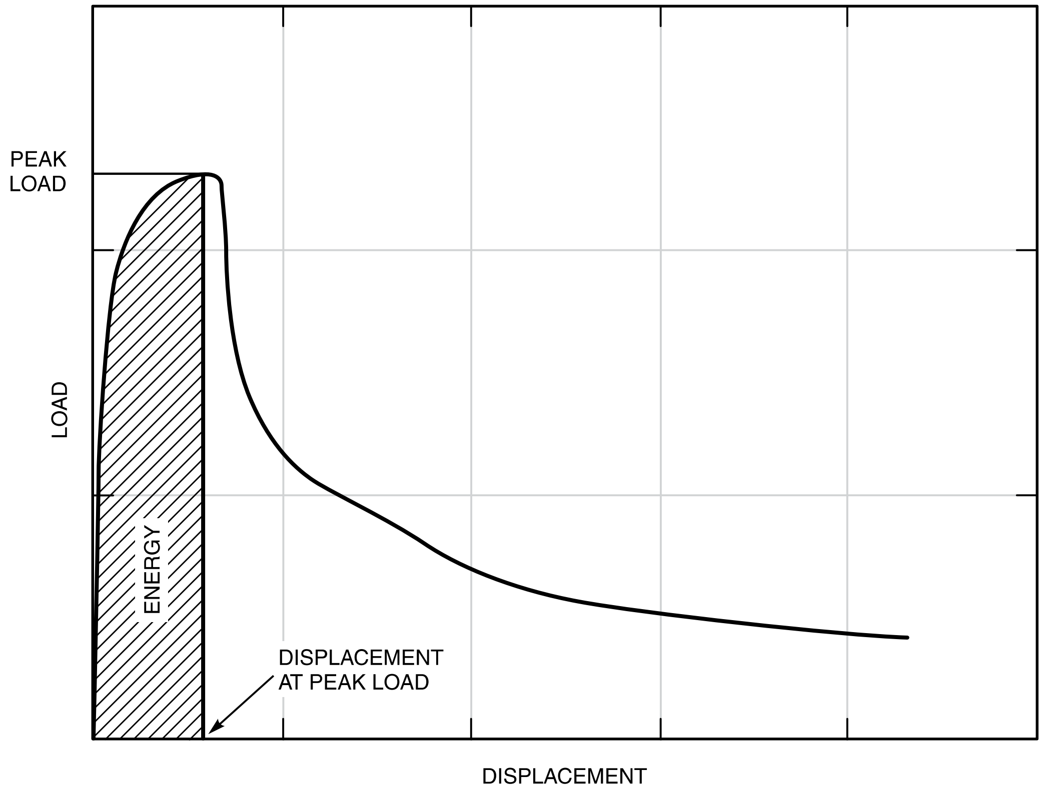



**Figure 23—Metrics Monitored in Shear and Cross Tension Tests**

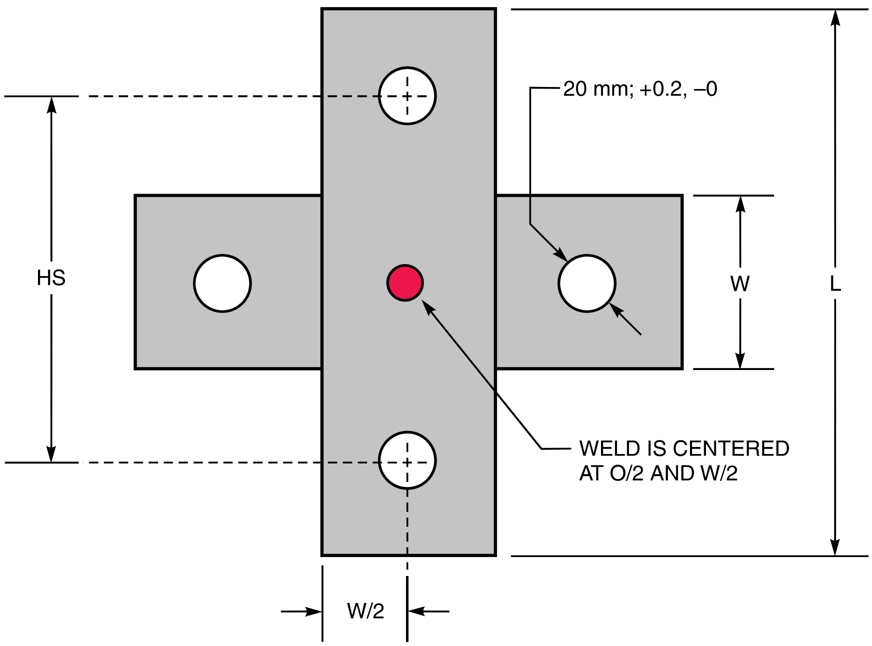



**Figure 24—Schematic for Cross Tension Samples**

**Table 4**
**Cross Tension Sample Dimensions**

| Sheet Thicknessl (mm) | Coupon Length L[a] (mm) | Coupon Width W[b] (mm) | Overlap O (mm) | Hole Spacing HS[c] (mm) |
|---|---|---|---|---|
| 0.60–3.00 | 150 | 50 | 50 | 100 |

[a] Tolerance: +0, –0.5 mm.
[b] Tolerance: +0, –1.0 mm.
[c] Tolerance: ±0.2 mm.

# Annex A (Informative)
# Informative References

This annex is not part of AWS D8.1M:2007, *Specification for Automotive Weld Quality—Resistance Spot Welding of Steel,* but is included for informational purposes only.

American National Standards Institute (ANSI) Accredited Standards Committee Z49, 2005, *Safety in Welding, Cutting, and Allied Processes*, ANSI Z49.1:2005, Miami: American Welding Society.

Aerospace Material Specification (AMS), AMS-W-6858D—*Welding, Resistance: Spot and Seam.*

American Welding Society (AWS) C1 Committee on Resistance Welding, 2000, *Recommended Practices for Resistance Welding*, AWS C1.1M/C1.1:2000, Miami: American Welding Society.

American Welding Society (AWS) D8 Committee on Automotive Welding, 2005, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, AWS D8.7M:2005, Miami: American Welding Society.

American Welding Society (AWS) Safety and Health Committee, 2004, *Effects on Welding and Health* (I through XI), Miami: American Welding Society.

International Iron and Steel Institute (IISI), 2006, *Advanced High Strength Steel (AHSS) Application Guidelines, 6 June 2006.*

International Organization for Standardization (ISO), ISO/TS 16949, *Quality Systems — Automotive suppliers — Particular requirements for the application of ISO 9001:2000.*[3]

Occupational Safety and Health Administration (OSHA), *Code of Federal Regulations,* Title 29 Labor 1910.1 to 1901.1450.

Quality System Requirements, QS-9000, Third Edition.

[3] AIAG documents are published by the Automotive Industry Action Group, Dept. 77839, P.O. Box 77000, Detroit, MI 48277.

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# Annex B (Informative)

# Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS D8.1M:2007, *Specification for Automotive Weld Quality—Resistance Spot Welding of Steel,* but is included for informational purposes only.

## B1. Introduction

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

## B2. Procedure

All inquiries shall be directed to:

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

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

**B2.1 Scope.** Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

**B2.2 Purpose of the Inquiry.** The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

**B2.3 Content of the Inquiry.** The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

**B2.4 Proposed Reply.** The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

## B3. Interpretation of Provisions of the Standard

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

## B4. Publication of Interpretations

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

## B5. Telephone Inquiries

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

## B6. AWS Technical Committees

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

## List of AWS Documents on Automotive Welding

| Designation | Title |
|---|---|
| D8.6 | *Specification for Automotive Resistance Spot Welding Electrodes* |
| D8.7M | *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding* |
| D8.8M | *Specification for Automotive Components Weld Quality—Arc Welding of Steel* |
| D8.9M | *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials* |
| D8.14M/D8.14 | *Specification for Automotive Components Weld Quality—Arc Welding of Aluminum* |

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