

ANSI/AWS/SAE/D8.9-97
An American National Standard



Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials



American Welding Society

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Key Words — Resistance spot welding, endurance test, peel test, weld button, endurance limit, hold-time sensitivity, shear tension strength, cross tension strength, weld property tests

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Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials

Prepared by
AWS/SAE Joint Committee on
Automotive Welding

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This document presents recommended practices for evaluating the resistance spot welding behavior of automotive sheet steels. The document contains a number of tests and test methods useful in determining the spot welding performance of coated and uncoated automotive sheet steels of all strength levels and compositions. The test methods are designed to assess current range, electrode endurance, and weld properties of automotive sheet steels. The weld property tests include tests for hold time sensitivity, weld hardness, shear-tension strength, and cross-tension strength. The document and the test methods, parameters, and test criteria it contains are designed exclusively for laboratory testing and are not intended as recommended practices or standards for manufacturing operations.

A Joint Publication of



American Welding Society

550 N.W. LeJeune Road, Miami, Florida 33126

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Foreword

(This Foreword is not part of ANSI/AWS/SAE D8.9-97, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steels Materials*, but is included for information purposes only.)

Over the years, a number of independent test methods for evaluating the resistance spot welding behavior of automotive sheet steels have evolved. Many of these test methods were developed to test for a specific welding performance, such as electrode life, current range, weld properties, etc. This diversity of test methods had been a detriment to evaluating the resistance spot weldability of sheet steels using common test methods whose results could be meaningfully compared.

This committee has resolved that publication of a document containing standard test methods through the American Welding Society (AWS) is highly desirable and beneficial to automotive companies, their suppliers, and others involved with resistance spot welding of sheet steel. The test methods contained in this document were originally developed under the guidance of the Auto/Steel Partnership's (A/SP) Standardized Welding Test Task Force and were originally published as the *A/SP Weld Quality Test Method Manual* in 1995. Because A/SP is not an official industry standards-writing body, the A/SP task force decided to submit the content of their document to AWS for inclusion in this publication. The test methods in the A/SP manual are very similar to those proposed by the AWS D8D Subcommittee in the past few years. This document not only contains recommended test methods for evaluating the welding behavior of sheet steel, but also covers areas essential to using these test methods in obtaining an accurate assessment of the material and its welding attributes. Listed below are the key elements of this document:

- (1) Sampling and characterization of test material
- (2) Equipment setup and electrode installation
- (3) Electrode conditioning and weld size stabilization
- (4) Endurance (electrode life) testing
- (5) Current level/current range testing
- (6) Weld property testing

The sampling and material characterization procedures, equipment setup and electrode installation procedures, and electrode conditioning/weld size stabilization procedures are common to all test methods. In the endurance test, the *endurance limit* (defined as the number of acceptable welds made during the test) is the key welding performance measure that is determined by this test. Other welding behavior measures determined in this test are current levels and current range. Weld-button characteristics are assessed by destructive peel testing of weld samples. The weld property tests are designed to determine hold-time sensitivity, shear tension strength, cross tension strength, metallurgical properties, and hardness of welds made with the test material. Current levels and current range are also determined in this test. The types of tests to use shall be specified by the party for whom the testing is to be performed. For some materials, all tests may be specified, while for others, only one test may be specified.

Comments and suggestions for the improvement of this document are welcome. They should be sent to the Secretary, AWS/SAE Joint Committee on Automotive Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials

1. Introduction

1.1 Scope. This document contains several standardized test methods that are designed for evaluating the resistance spot welding behavior of coated and uncoated sheet steels in a laboratory environment. The test procedures allow for standardized testing of automotive sheet steels to determine the following:

- (1) The effect of the interaction between a sheet steel's coating (metallic, non-metallic, or both) and the welding electrodes on electrode deterioration and weld size/quality behavior over an extended number of welds
- (2) Current levels and current ranges
- (3) Mechanical properties of welds at different weld sizes and hold times
- (4) Metallurgical and hardness properties of welds

The test methods are intended to be applied in a laboratory environment to characterize certain aspects of the welding behavior of sheet steel products under highly controlled experimental conditions. **They are not intended to simulate production welding practices or to predict welding performance in production operations.** The test methods are to be used for sheet steels ranging in yield strength levels from 140 MPa to 420 MPa and ranging in thickness from 0.6 mm to 3.0 mm. In the endurance test, a minimum of two tests per material is recommended to obtain an accurate assessment. Replications of the other tests are at the discretion of the user or the specifying party. The specific types and number of tests that are required shall be left to the specifying party. While these test methods were developed to compare the welding behavior of different materials, they can be judiciously applied to evaluate other aspects of welding behavior. Resistance spot welding behavior is dependent upon a wide variety of interacting material and weld process factors.

To obtain repeatable and reproducible performance data, it is imperative that all experimental variables and the way a test is conducted be closely controlled. Therefore, the instructions for the various sampling and testing procedures in this manual are stated in mandatory language (even though this document is classified as a Recommended Practice document), and should be followed as closely as possible. Deviations from the prescribed procedures or test methods, permissible with the consent of the party for whom the testing is performed, have to be noted and reported.

1.2 Safety Precautions. Resistance welding and allied processes can be safely performed with minimum health risks if proper safety procedures and precautions are taken. Remember the following:

- (1) **FUMES AND GASES** may be hazardous to your health. Inhalation of fumes should be avoided and adequate ventilation or an exhaust system should be used to remove fumes and gases from the work area.
- (2) **INFRARED RADIATION (HEAT)** can burn. Proper safety attire and suitable gloves should be worn when handling hot samples.
- (3) **ELECTRIC SHOCK** can kill. Live electrical or electronic components must never be touched. Equipment instructions, applicable Material Safety Data Sheets (MSDS), and the employer's safety practices or Job Safety Analyses (JSAs) should be read and followed.

Safety guidelines, practices, and precautions can be found in the latest edition of ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society (AWS). In addition to ANSI/ASC Z49.1, safety guidelines and practices pertaining to resistance welding can be found in the Safety Fact Sheets published by AWS, some of which are listed here. For a complete up to date listing contact AWS:

- (1) Fumes and Gases
- (2) Noise
- (3) Chromium and Nickel in Welding Fumes
- (4) Electrical Hazards
- (5) Fire and Explosion Prevention
- (6) Burn Protection
- (7) Mechanical Hazards
- (8) Tripping and Falling
- (9) Falling Objects
- (10) Confined Spaces
- (11) Contact Lens Wear
- (12) Graphic Symbols for Precautionary Labels
- (13) Ergonomics

1.3 Standard Units of Measurement. All units in this document are in hard metric. Metric was purposely selected for ease of use, because metric is the standard unit of the United States, because automotive companies have converted to metric, and so that the document may be internationally usable. If necessary, conversions of units of measurement shall be performed according to ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*. It is highly recommended that all measurements be made with metric instruments in the application of these test methods. If this is not possible and non-metric instruments are used, it shall be noted on all data and report sheets that non-metric instruments were used and that the values recorded or reported are conversions from non-metric measurements.

2. Terms and Definitions

All of the terms listed in this section are used in various parts of this document and require definition for correct interpretation of the instructions. Most of these terms are not contained in ANSI/AWS A3.0-94, *Standard Welding Terms and Definitions*. Some of the terms are listed in ANSI/AWS A3.0-94, but their definitions have been enhanced to clarify their use in this document.

anchor weld. The first of two welds made on a peel-test sample.

average weld-button size. The mean of all weld-button sizes (peel sample test welds) determined at a given checkpoint.

checkpoint. The location in the test sequence where specific weld-button size or weld-button-size/fracture-mode criteria are determined.

composite tip imprint. A carbon-paper impression produced on a piece of white paper that shows the combined contact pattern of the top and bottom electrode faces when the electrodes are brought into direct (without the

presence of any test coupon) contact with each other under full welding force.

coupon. A single, small piece of test material with specified dimensions that is used to make up test samples.

cross tension test. A destructive test to measure spot weld strength and button size with the test weld in the plane perpendicular (direct tension) to the applied load.

cross tension test coupon. A coupon, cut from a coupon strip (see Figure 3A) in accordance with Table 2 with its length parallel to the direction of rolling, used to make up a cross tension test sample.

cross tension test sample. A lap-joint test sample, composed of two cross tension test coupons having a specified overlap and standard size, that is used to determine the direct tension strength of the test weld and its fracture mode.

current. The effective (RMS) welding current of a spot weld that is measured at the secondary side of the welding transformer and is calculated by an integrating current meter.

current level. The current required to produce a specific weld size or expulsion criteria in one or more spot welds.

current range. The difference in welding current between the I_{MIN} and I_{MAX} currents.

current setting. The programmed welding current (in kA) of an electronic spot weld controller that is capable of constant current control or the percent heat or percent current setting that is used to set the welding current on some constant-voltage-type welding controllers.

dressed electrode-face diameter. The mean diameter of the electrode surface (that which contacts the sheet surface) after the electrode faces are paralleled and adjusted (dressed) to size. This dimension is calculated by subtracting the tip-imprint correction factor (CF) from the individual tip-imprint diameters.

effective (RMS) welding current. The integrated current (amperage) of a weld that is equivalent in its heating or power capability to pure dc (direct current).

electrode-face diameter. The mean diameter of the electrode surface (that which contacts the sheet surface) before the electrode is dressed. This dimension is the as-ordered or as-machined diameter measured prior to electrode installation.

electrode-face diameter weld size (FDWS). The mean diameter of a weld button that is equal to the *specified* dressed electrode-face diameter (see Table 5.2) of the electrodes being used.

electrode sticking criterion. The condition at which severe sticking between the electrode and the peel-test sample is noted so that pressure applied with a finger at the farthest end of the stuck sample results in permanent deformation (bending) of the peel-test sample before breaking free from the electrode.

endurance limit. The total number of acceptable welds made during the endurance test. This number does not include welds made during the weld-size stabilization procedure or welds made as part of the initial I_{MIN} and I_{MAX} determinations.

endurance test termination criterion. When all five weld buttons fall below the specified minimum weld size at two consecutive checkpoints.

expulsion. The ejection of molten metal from the faying interface (interface between the two test coupons) of the sample. Expulsion may be verified by destructive peel testing of the sample and observing whether metal "whiskers" or "fingers" are evident at the interface.

fracture or pullout mode. The appearance of the weld button after peel testing.

full interfacial fracture (FIF). A fracture mode of a spot weld where all of the weld nugget (fused area of a spot weld) separates through the plane of the weld.

hold-time sensitivity (HTS) panel coupon. A coupon, cut in accordance with Table 2, used to make up a HTS panel sample. The rolling direction is as noted in Table 2.

hold-time sensitivity (HTS) panel sample. A stackup of two HTS panel coupons used for making test welds in the HTS test.

hold-time sensitivity (HTS) test. A test that determines the behavior or properties of spot welds made on the test material under different weld cooling rates. This test is accomplished by making a series of seven welds on HTS panel samples at short and long hold times for MWS and FDWS weld-button sizes. The welded HTS panel samples are then sectioned into individual samples (one weld per sample) that are destructively peeled. Weld-button size and fracture modes are then determined. (See 10.3)

I_{FDWS} current. The lowest current that produces weld buttons which meet the electrode-face diameter (FDWS) button-size criterion and the full or oval button fracture-mode criterion. The current measured for the test weld of any sample is used when determining the I_{FDWS} current. The I_{FDWS} current is the mean of the test weld currents for the three samples that meet the I_{FDWS} criteria.

I_{MAX} current. The lowest current (from a peel sample's test weld) that meets either the I_{MAX} expulsion criterion (expulsion on both anchor and test welds) or the I_{MAX} electrode sticking criterion (severe sticking on both an-

chor and test welds). The current measured for the second weld (test weld) of the appropriate peel-test sample is the I_{MAX} current.

I_{MIN} current. The lowest current that produces weld buttons which meet the minimum button size (MWS) criterion and the full or oval button fracture-mode criterion. The current measured for the test weld of any sample is used when determining the I_{MIN} current. The I_{MIN} current is the mean of the test weld currents for the three peel samples that meet the I_{MIN} criteria.

I_{OP} current. The fixed welding current at which the endurance test is run. The magnitude of I_{OP} is approximately 200 A below I_{MAX} . If the difference between I_{MAX} and the current at the next lower setting is greater than 200 A, then I_{OP} is the current that corresponds to the closest setting below I_{MAX} .

individual tip imprint. A carbon-paper impression produced under full welding force on a piece of white paper that shows the individual contact pattern of each electrode face (top and bottom electrodes) separately.

micro-hardness/metallographic sample. A test sample (taken from one of the HTS panels) that is sectioned across the centerline of the weld (perpendicular or parallel to the length of the sample from which it is extracted), mounted, polished, and etched for metallographic examination and micro-hardness testing.

material characterization panel (MCP). A steel panel (see Figure 4 for dimension and marking details) that is used in determining sheet thickness, coating weight, coating composition, and substrate composition. Mechanical properties and surface roughness may also be determined from this panel if so desired.

minimum weld-button size (MWS). The minimum weld-button size is calculated by using the following formula:

$$MWS = 4\sqrt{t}, \text{ where } t = \text{avg. sheet thickness in mm, rounded to the closest 0.01 mm, and where } MWS \text{ is rounded to the closest 0.1 mm.}$$

panel coupon. A coupon, cut in accordance with Tables 1 or C1, used to make up a panel sample. The direction of rolling is unimportant.

panel sample. A stackup of two panel coupons used for making rows of welds during the endurance test.

partial interfacial fracture (PIF). A fracture mode of a spot weld where a part of the weld nugget (fused area of a spot weld) separates through the plane of the weld and some portion of the weld pulls out as a partial button.

peel test. A destructive test for determining a spot weld's pullout mode and button size. The test involves mechanically separating the lap joint by peeling.

peel-test coupon. A coupon, cut from a coupon strip (see Figure 3A) in accordance with Table 1 with its length parallel to the direction of rolling, used to make up a peel-test sample.

peel-test sample. A lap-joint test sample, composed of two peel-test coupons having a specified overlap and standard size, that is used to determine the weld-button size and fracture mode of a resistance spot weld. See Table 4 and Figure 5 for details.

percent current. The designation for the control used to set the welding current on some constant-voltage welding controllers.

percent heat. The designation for the control used to set the welding current on some constant-voltage welding controllers.

rolling direction (RD) mark. A mark made prior to coil-edge removal along the coil edge of a steel sheet, as shown in Figure 1, that identifies the rolling direction. Also see the definition of Transferred RD Mark.

secondary edge. The edge of peel coupon strips or the material characterization panel that is perpendicular to the rolling direction. See Figure 2.

shear tension test. A destructive test to measure spot weld strength and button size with the test weld in the same plane (shear orientation) as the applied load.

shear tension test coupon. A coupon, cut from a coupon strip (see Figure 3A) in accordance with Table 2 with its length parallel to the direction of rolling, used to make up a shear tension test sample.

shear tension test sample. A lap-joint test sample, composed of two shear-test coupons having a specified overlap and standard size, that is used to determine the shear strength of the test weld and its fracture mode.

stabilization weld size (SWS). The stabilization weld size, used during the electrode-face and weld-size stabilization procedure, is calculated by using the following formula:

$$SWS = 0.9 \times \text{target dressed face diameter (listed in Table 3). SWS is rounded to the closest 0.1 mm.}$$

test weld. The weld made on any sample that is to be used to determine weld size, weld strength, button fracture mode, or in combination.

tip-imprint correction factor (CF). The average difference between the individual tip-imprint diameters and the actual electrode-face diameters of the top and bottom electrodes before dressing. These differences (the tip imprints always being larger than the actual electrode-face diameters if the electrode face is flat) are caused by the compression of the white and carbon papers. This compression results in slightly larger imprints (~0.1 to 0.3

mm larger) than the actual face diameters because a small portion of the electrode bevel at the face edge becomes imprinted. Thicker white paper will generally produce slightly larger imprints and will result in larger correction factors. The correction factor (CF) is used to calculate the actual electrode-face diameters during the electrode dressing procedure by subtracting the CF from the tip imprints.

tip-imprint diameter. The mean of the maximum and minimum diameters of composite or individual tip imprints.

top surface. For sheets with nominally equal coating weight on both sides, the top surface is the surface facing up (toward the viewer) in a stack of sheets. For differentially coated sheets, this is the side having the heavier coating weight. *Note: If the heavier side of differentially coated sheets is not known or coded, preliminary coating weight analyses shall be performed as per 4.3 before proceeding with any marking and shearing operations.*

top surface identification (ID) mark. A mark used to indicate the top surface of an untrimmed sheet, as shown in Figure 1. This mark should be made long enough so that after trimming the sheet, the mark is still visible as shown in Figure 2.

transferred rolling direction (RD) mark. An RD mark that is transferred to all coupon strips and the material characterization panel in subsequent shearing operations. Individual coupons do not need to be marked with an RD mark.

transferred top surface identification (ID) mark. A mark placed along the secondary edge of the top surface of peel coupon strips (Figure 3A), panel coupon strips (Figure 3B), or the material characterization panel (Figure 4).

weld button. The part of a spot weld, including all or part of the nugget, which tears out during destructive testing of welded samples.

weld-button size. The average of the minor and major dimensions of the weld button.

welding rate. The frequency, expressed in welds per minute, at which welds are made on the panel samples.

3. Sample Preparation

3.1 Coupon Sizes

3.1.1 Peel Test And Endurance Test Panel Coupons. See Table 1.

3.1.2 Hold-Time Sensitivity (HTS) Panels, Shear Tension Coupons, and Cross Tension Coupons. See Table 2.

3.1.3 Material Characterization Panel (MCP). 250 mm X trimmed sheet width (full coil width minus

Table 1
Coupon Dimensions and Estimated Material Requirements (Endurance Test)

Sheet Thickness (mm)	Peel Test Coupons		Endurance Test Panel Coupons		Estimated Area Requirements/Replication ^g		
	Length ^{a,b} (mm)	Width ^b (mm)	Length ^c (mm)	Minimum Width ^d (mm)	Area 1 Stabilization Procedure (m ²) ^f	Area 2 I _{MIN} /I _{MAX} Tests (m ²) ^f	Area 3 ^{d,e} Endurance Test (m ² /weld) ^f
0.60–0.69	100	30	320	52	0.633	0.600	0.000982
0.70–0.89	100	30	340	55	0.674	0.600	0.001085
0.90–1.29	120	40	400	64	0.992	0.960	0.001520
1.30–1.69	140	50	460	73	1.372	1.400	0.002029
1.70–2.09	140	50	520	82	1.553	1.400	0.002482
2.10–3.00	140	50	580	91	1.756	1.400	0.002989

Notes:

a. Rolling direction is parallel to this dimension.

b. Tolerance: ± 1 mm.

c. Tolerance: ± 5 mm; any rolling direction is acceptable.

d. Width may be increased to ease handling. If panel width is increased, a new m²/weld coefficient (Area 3) has to be calculated for the new width.

e. Coefficient for dimensions shown. Area 3 multiplier for the optional panels is listed in Table C1 of Annex C.

f. 1 m² = 10.764 ft.²

g. Total estimated material requirements (area) per replication = $1.3 \times [\text{Area 1} + \text{Area 2} + (\text{Area 3} \times \text{Expected No. of Endurance Welds})]$. For example, for a 0.8 mm thick sheet with an expected endurance limit of 5000 welds:

Total Required Area Per Replication = $1.3 [0.674 \text{ m}^2 + 0.600 \text{ m}^2 + (0.001085 \text{ m}^2/\text{weld} \times 5000 \text{ welds})] = 8.71 \text{ m}^2$ or ~94 square feet. See 3.2 for complete instructions.

Table 2
Coupon Dimensions and Estimated Material Requirements (Weld Property Tests)

Sheet Thickness (mm)	Hold-Time Sensitivity (HTS) Panel Coupons		Shear Tension Coupons		Cross Tension Coupons		Estimated Required Area 4/ Replication (m ²) ^{f,g}
	Length ^{a,b} (mm)	Width ^b (mm)	Length ^{a,c} (mm)	Width ^b (mm)	Length ^{a,d} (mm)	Width ^e (mm)	
0.60–1.29	140	350	105	45	150	50	3.0
1.30–3.00	140	350	138	60	150	50	3.5

Notes:

a. Rolling direction is parallel to this dimension.

b. Tolerance: ± 2 mm

c. May be increased.

d. Tolerance: +0, -0.5 mm

e. Tolerance: +0, -1.0 mm

f. Total material requirement (area) for weld property tests per replication. Area 4 includes estimated requirements for electrode stabilization procedure, I_{MIN}/I_{MAX} tests, and all other weld property tests.

g. 1 m² = 10.764 ft.²

200 mm). The 250 mm dimension shall be parallel to the rolling direction of the material. *Note: Only one MCP is required per material.*

3.2 Total Sheet Quantity Requirements. If both the endurance test and all of the weld property tests are to be performed, their estimated areas shall be added.

3.2.1 Endurance Test. The required estimated area for each test replication of the Endurance Test (EA/R) shall be calculated using the following formula and the areas given in Table 1 or Table C1:

$$\text{EA/R} = \text{Area 1} + \text{Area 2} + (\text{Area 3} \times \text{The expected number of endurance welds})$$

The total area required shall be calculated by multiplying the EA/R by the number of replicates (minimum of two) times a scrap loss factor (estimate includes MCP and trimmed edges) as shown by the following formula:

$$\text{Total Area For Endurance Tests} = \text{Number of Replicates} \times \text{EA/R} \times 1.3$$

Approximately 100 peel-test coupons and 6 to 20 standard panel coupons are required for the weld size stabilization procedure. Approximately 200 peel-test coupons are required for the I_{MIN} and I_{MAX} current determinations in the endurance procedure. Approximately 50 peel-test coupons and 50 standard panel coupons are required for every 1000 welds made during the endurance test. When using the optional panels, approximately 20 optional panel coupons (see Annex C) are required per 1200 welds.

3.2.2 Weld Property Tests. The required estimated area for each test replication of the Weld Property Tests

(WPA/R) shall be determined using the appropriate Area 4 given in Table 2.

$$\text{WPA/R} = \text{Estimated Area 4 (from Table 2)}$$

The total area required shall be calculated by multiplying the WPA/R by the number of replicates times a scrap loss factor (estimate includes MCP and trimmed edges) as shown by the following formula:

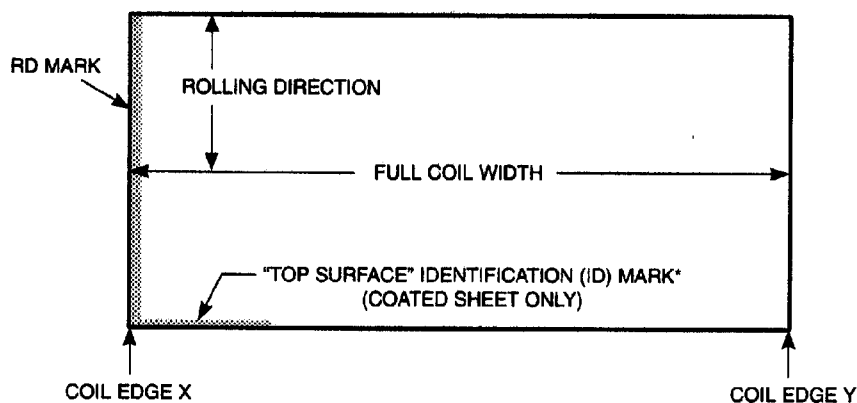
$$\text{Total Area For Weld Property Tests} = \text{Number of Replicates} \times \text{WPA/R} \times 1.3$$

Approximately 100 peel-test coupons and 6 to 20 conditioning panel coupons are required for the weld size stabilization procedure. Approximately 100 peel-test coupons are required for the I_{MIN} and I_{MAX} current determinations.

3.3 Rolling Direction (RD) Orientation. See Tables 1 and 2.

3.4 Shearing Details. The test material shall be sheared so that the transferred "top surface" identification (ID) mark appears on all strips, panels, and coupons of coated sheet steels. Uncoated materials do not require this surface ID mark. The transferred rolling direction mark is only required on all coupon strips prior to coupon shearing and on the material characterization panel. Individual test or panel coupons do not require an RD mark.

3.4.1 Sheet Surface and Rolling Direction Identification. All sheets shall be labeled with marks that identify the "top surface" (see section 2 for definition) and the rolling direction (RD) prior to performing any shearing (see Figure 1). These marks shall be transferred to



*NOTE: MAKE THIS MARK LONG ENOUGH SO THAT IT IS NOT LOST AFTER COIL EDGE TRIMMING.

Figure 1—Surface and Rolling Direction Marking of Sheet

strips and coupons (as required) in subsequent shearing operations.

3.4.2 Coil Edge Removal. To eliminate any potential effects of edge coating weight and sheet thickness variations on test results, 100 mm from each sheet's coil edges (X and Y) shall be sheared off and scrapped. After trimming Edge X, the RD mark shall be transferred as shown in Figure 2. Figure 2 also shows a typical layout for extracting peel coupon strips and the material characterization panel.

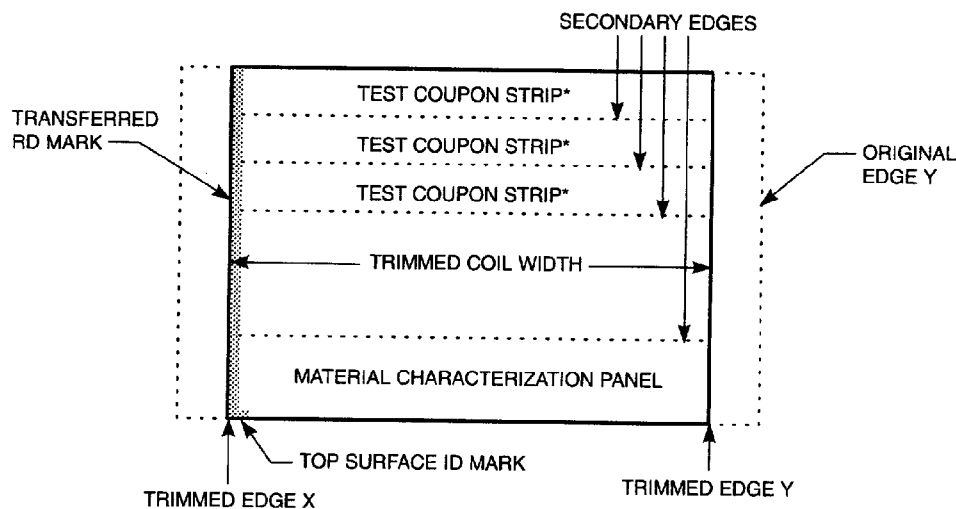
3.4.3 Test and Panel Coupon Shearing. The desired test coupon strips, panel coupon strips, or both shall be sheared from the trimmed sheet. The transferred RD mark shall appear on all such strips to serve as a reference for transferring the top surface ID mark to the secondary edge of test coupon strips of coated sheet. Using the RD mark as a reference, the top surface ID mark shall be transferred to the secondary edge of each coupon strip of coated sheet, as shown in Figures 3A and 3B. Unmarked coupons (test or panel) of coated sheet shall be discarded. All test coupons, except panel coupons for the endurance test, shall be sheared so that they have the proper rolling direction orientation (see Tables 1 and 2). Because panel coupons for the endurance test are not required to have a specific rolling direction orientation, their top surface ID mark may be located on either their short edges (width) or long edges (length) as shown in Figure 3B.

3.4.4 Material Characterization Panel Shearing.

One MCP shall be sheared from any trimmed sheet as illustrated in the Figure 2 example. If sheared correctly, the transferred RD mark will appear on the trimmed X edge. On coated sheet, the transferred top surface ID mark shall be marked on the secondary edge of the panel. The transferred RD mark should be used as a reference, as shown in Figure 4. Marks shall also be made at the 1/4, 3/8, center, 5/8, and 3/4 points of the panel width (trimmed coil width). Samples to be extracted from this panel require these location markings for sampling at the specified locations. Unmarked samples shall be discarded.

3.5 Surface Preparation. All samples shall be wiped to evenly distribute mill oils (if present) and to remove surface contaminants such as dirt, grease, etc. No solvent of any kind may be used to clean or degrease the samples. The purpose of wiping is not intended to remove mill oils but to redistribute them evenly. Any oil or dirt picked up during shearing operations shall be removed by lightly wiping the samples before using them. Samples with surface deposits, contamination, etc. that cannot be removed by light wiping shall be discarded.

3.6 Sample Randomization. All test coupons shall be thoroughly mixed in a sufficiently large container to obtain a well-randomized mixture of coupons from within a sheet and between a group of sheets. Panel coupons for the endurance test do not need to be randomized because surface orientations will be varied (see 5.6.2).



*NOTE: FOR HTS PANEL, PEEL, SHEAR TENSION, AND CROSS-TENSION COUPONS.

Figure 2—Trimmed Coil Width with Transferred RD Mark on Sheet

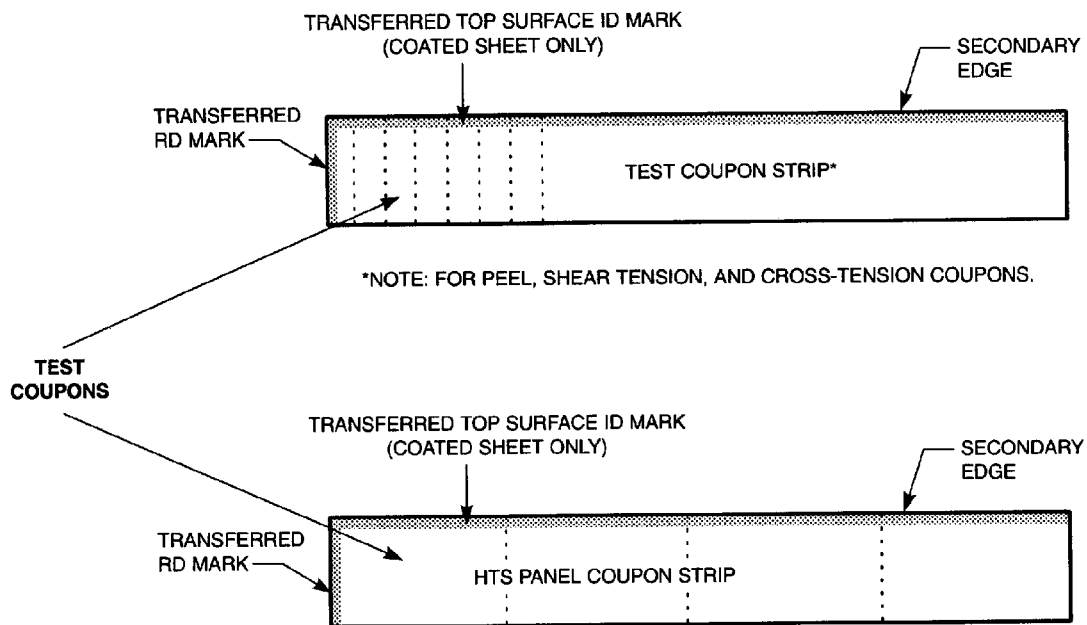


Figure 3A—Test Coupon Strips with Transferred Marks

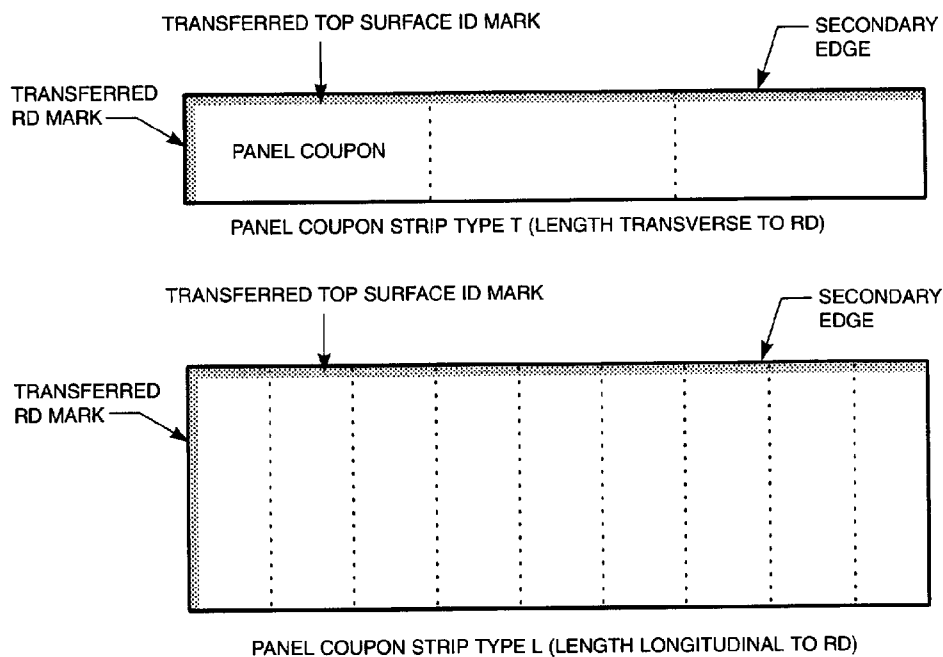


Figure 3B—Endurance Test Panel Coupon Strips with Transferred Marks

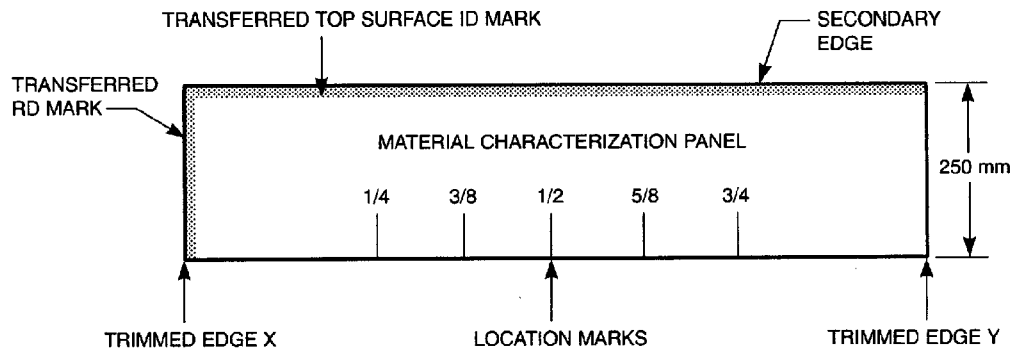


Figure 4—Material Characterization Panel with Transferred Marks

4. Material Characterization

All samples for material characterization shall be cut from the Material Characterization Panel (MCP), being certain to keep surface, rolling direction, and location marks or codes on all samples and scrap pieces (for possible retests). For tests other than official material qualification tests, it is highly desirable, but not mandatory, that all of the material characteristics listed in section 4 be determined and recorded. For official material qualification tests, all items in section 4 that are specified by the party for whom the tests are to be performed shall be determined and recorded on the Test Material Data Sheet (Form B-3) or a similar form.

4.1 Sheet Identification. The following information or data about the test material shall be obtained and recorded.

- (1) Coil identification number or code
- (2) Substrate grade and material specification (if applicable)
- (3) Coating type and weight grade (nominal weight designation)
- (4) Surface lubricants, postcoating treatments or both
- (5) Measured full sheet width before edge trimming and trimmed sheet width

4.2 Sheet Thickness. Before extracting any samples from the MCP, the sheet thickness shall be measured at five positions of the panel width (trimmed edge X, 1/4 point, center, 3/4 point, and trimmed edge Y) to the nearest 0.01 mm. The average of the five readings shall be calculated and rounded to the closest 0.01 mm. All data shall be recorded on the Test Material Data Sheet (Form B3) or a similar form. The mean thickness shall also be recorded on the Welding Data Sheet (Form B1) or a similar form.

4.3 Coating Weight. Coating weight shall be determined at the locations of the MCP listed below for each surface (top [marked side] and bottom) of the sheet by means of any accepted standard method [such as ASTM A 90 (weigh, strip, weigh), ASTM A 754 (X-ray fluorescence), etc.]. *Note: The test method that is used shall be recorded on the Test Material Data Sheet (Form B3) or a similar form.*

- (1) Trimmed edge "X" (Duplicate measurements from each surface)
- (2) Trimmed edge "Y" (Duplicate measurements from each surface)
- (3) Center of coil width (Duplicate measurements from each surface)

4.4 Coating Composition. Coating composition shall be determined for each surface (top [marked side] and bottom) of the MCP. The locations at which samples are to be extracted are listed below for the various coating types. Analyses shall include the elements listed for the coating type. All data shall be recorded in weight percent.

(1) Hot Dip Zn (Galvanized) and Hot Dip ZnFe (Galvannealed)

Elements: Zn, Al, Fe, Pb, Sb
Location: Between 1/4 and 3/4 points

(2) Electrolytic Zn (Electrogalvanized)

Elements: Zn, Fe
Location: Between 1/4 and 3/4 points

(3) Electrolytic ZnNi

Elements: Zn, Ni, Fe
Location: Between 1/4 and 3/4 points

(4) Electrolytic ZnFe

Elements: Zn, Fe
Location: Between 1/4 and 3/4 points

4.5 Substrate Composition. Substrate composition samples may be taken from any location on the Material Characterization Panel. Analyses shall include all elements relevant to the grade of steel being tested.

4.6 Mechanical Properties (if required). Longitudinal tensile samples shall be taken at the center point of the Material Characterization Panel. Properties typically determined are yield strength, ultimate tensile strength, percent elongation, N value, and R value. All testing shall be performed per ASTM standards, and the ASTM number of the standard shall be reported on the Test Material Data Sheet (Form B3) or a similar form.

4.7 Surface Roughness (if required). Surface roughness of each sheet surface (top and bottom) shall be determined per standard procedures such as ANSI B46.1, SAE J911, etc.

5. Welding Parameters

5.1 Electrode Specifications and Dimensions. See Annex A.

5.2 Welding Variables

5.2.1 Electrode Size and Dressed Face Diameter. The electrodes specified in Table 3 for the thickness of sheet being welded shall be used. A tolerance of ± 0.1 mm from the specified dressed face diameter (listed in Table 3) shall be maintained for the final dressed face diameter.

5.2.2 Squeeze Time. The squeeze time shall be adjusted as needed to ensure that the force is at ≥ 98 percent of static force value at initiation of welding current (target is 100 percent of static force). (Note: The squeeze-time setting required to achieve this will vary with machines; 45–90 cy are typical.)

5.2.3 Electrode Force. The force shall be adjusted to the specified value in Table 3 for the thickness of sheet being welded. Electrode force tolerance is ± 2 percent of the value listed in Table 3.

5.2.4 Weld Time. Weld time shall be adjusted to the specified values in Table 3 for the thickness of sheet being welded. Weld time (and other programmed times) is in number of cycles at a line frequency of 60 Hz.

5.2.5 Welding Current. Welding current is to be adjusted as needed or as specified. Allowable percent heat or percent current settings on the welding control shall be ≥ 60 percent and ≤ 92 percent (change tap settings as needed to stay within this range). See 6.1.3 for details.

5.2.6 Hold Time. Hold time shall be adjusted to the "short" hold time for the endurance test (see Table 3) and to the specified hold time (short or long) in the weld property tests. All hold times are programmed times and do not reflect actual contact time.

5.2.7 Off Time. Off time shall be adjusted as needed to meet the specified welding rate.

Table 3
Welding Parameters

Sheet Thickness (mm)	Electrode				Weld Time (cy)	Short ^f Hold Time (cy)	Long ^f Hold Time (cy)	Welding Rate ^d (w/min.)
	Type No. ^b	Dressed Face Dia. (mm)	Force (kN) ^c	Cooling (l/min.)				
0.60–0.69	1	4.5	1.6	4.0	10	5	90	25
0.70–0.79	2	5.0	2.0	4.0	11	5	90	25
0.80–0.89	2	5.0	2.2	4.0	12	5	90	25
0.90–1.09	3	6.0	2.8	4.0	13	5	90	20
1.10–1.29	3	6.0	3.1	4.0	14	5	90	20
1.30–1.49	4	7.0	3.8	6.0	16	10	90	15
1.50–1.69	4	7.0	4.2	6.0	18	10	90	15
1.70–1.89	5	8.0	5.0	6.0	20	10	90	15
1.90–2.09	5	8.0	5.5	6.0	22	10	90	15
2.10–2.49	6	9.0	6.4	6.0	15-1-15 ^e	10	90	15
2.50–3.00	6	9.0	7.0	6.0	20-1-20 ^e	10	90	15

Notes:

a. For tolerances and other details, see 5.2.1 through 5.3.

b. A/SP designation; see Annex A for electrode details.

c. 1 kN = 224.8 lbf.

d. Applies to conditioning panel welds of all tests and panel welds of the Endurance Test.

e. Denotes two pulses with 1 cycle off time between pulses.

f. See 5.2.6.

5.2.8 Welding Rate. The welding rate shall be adjusted to that specified in Table 3 when making panel welds for electrode conditioning and all panels welds made during the endurance test. The tolerance for the welding rate is ± 1 wpm. The welding rate shall be checked with a stopwatch and weld counter or some other suitable means. Adjustment of the "off time" or other "noncritical" parameters may be made to achieve the proper welding rate.

5.3 Electrode Cooling

5.3.1 Coolant Flow Rate. Coolant flow shall be adjusted to meet the rate specified in Table 3 at a tolerance of ± 5 percent.

5.3.2 Coolant Temperature. $+20^{\circ}\text{C}$; Tolerance: $\pm 5^{\circ}\text{C}$. *Note: If the coolant temperature is outside of the stated tolerance, this fact shall be noted on the welding data sheet.*

5.3.3 Cooling Tubes. Ends are to be cut at a 45 degree angle and positioned so that the tip contacts the electrode cooling hole face (see 6.11 for additional details).

5.4 Weld Spacing and Overlap. Weld spacing and overlap for all peel-test samples shall be kept at the specified distances listed in Table 4 and Figure 5. Weld spacing for all electrode conditioning welds and the endurance test panel welds shall be kept as listed in Table 5 and shown in Figure 6. Weld spacing and overlap for the weld property test samples are listed and shown in section 10, Weld Property Tests. Spacing is measured from weld center to weld center for all welds.

5.4.1 Peel-Test Samples. The specified weld spacing (WS), listed in Table 4, shall be maintained between the anchor weld (1st weld) and the test weld (2nd weld) on all peel samples (shown in Figure 5).

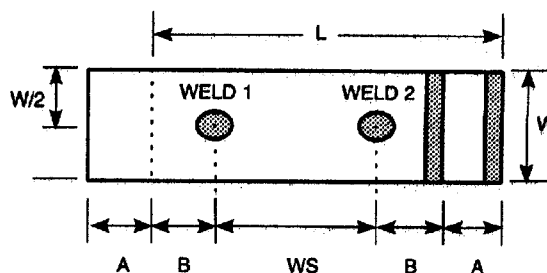


Figure 5—Weld Location, Spacing, and Coupon Overlap for Peel-Test Samples

5.4.2 Endurance Test and Electrode Conditioning Panel Samples. The specified weld spacings and edge distances (listed in Table 5) for the standard panel (shown in Figure 6) shall be maintained on all panel welds. The specified weld spacings and edge distances for the optional panel are listed in Annex C, Table C1. The panel type used shall be recorded on the Welding Data Sheet using code "S" for the standard panel and "O" for the optional type. If panel welding is performed manually, spacing marks may be *lightly* scribed on the top panel coupon or ink marks may be made at the coupon edges (not at the weld location) to act as weld position locators. Maintaining weld spacing within the allowed tolerances may be difficult without such locators. No ink, pencil, etc. marks are allowed where the weld will be made. **The only allowable marks over which welds can be made are light scribe marks produced with a metallic scribe.**

**Table 5
Weld Spacing and Edge Distances
for Endurance Test and Electrode
Conditioning Panel Samples**

Sheet Thickness (mm)	L ^a (mm)	Minimum W ^b (mm)	WS ^c (mm)	A ^d (mm)	B ^e (mm)
0.60–0.69	320	52	14	19	19
0.70–0.89	340	55	15	20	20
0.90–1.29	400	64	18	23	23
1.30–1.69	460	73	21	26	26
1.70–2.09	520	82	24	29	29
2.10–3.00	580	91	27	32	32

Notes:

a. $L = (18 \times WS) + 2A + 30$; Tolerance: ± 5 mm.

b. W may be increased to ease handling.

c. $WS = 3 \times$ Dressed electrode-face diameter; Tolerance: ± 3 mm.

d. A = the minimum edge distance; No specific tolerance.

e. Tolerance: ± 3 mm.

**Table 4
Weld Locations, Spacing, and Overlap
Dimensions for Peel-Test Samples**

Sheet Thickness (mm)	L ^a (mm)	W ^a (mm)	WS ^b (mm)	A ^b (mm)	B ^b (mm)
0.60–0.89	100	30	30	15	27.5
0.90–1.29	120	40	40	20	30
1.30–3.00	140	50	50	25	32.5

Notes:

a. Tolerance: ± 1 mm.

b. Tolerance: ± 3 mm.

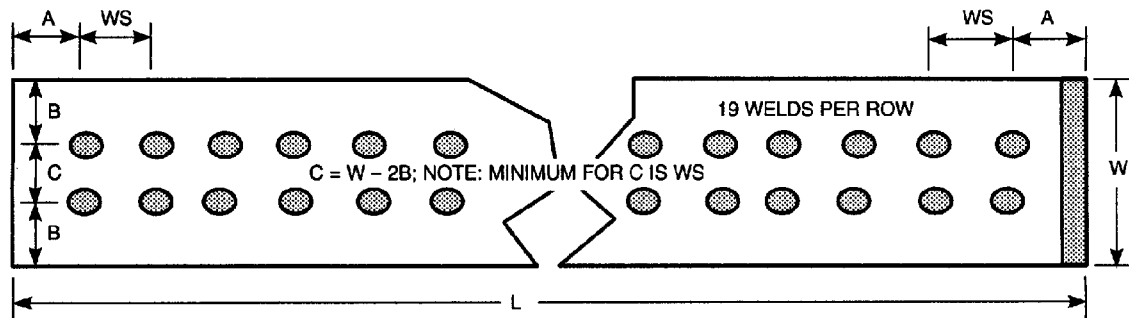


Figure 6—Weld Spacing and Edge Distances for Endurance Test and Electrode Conditioning Panel Samples

5.5 Sample Orientation and Sequencing

5.5.1 Peel-Test Samples. Peel-test samples are welded in three different orientations (with respect to the throat of the welder) during various segments of the test procedures. These orientations, designated C, L, and R, are shown in Figure 7.

5.5.2 Endurance Test and Electrode Conditioning Panel Samples. The first row of 19 welds on these panel samples shall be made with the panels oriented (with respect to the welding machine) as illustrated in Figure 8A. To make the second row of 19 welds, the panel samples are to be rotated 180 degrees in the horizontal plane to the orientation shown in Figure 8B.

5.5.3 Endurance Test Panel Sequencing. Panel welds shall be made one row at a time on different, consecutive panels (with a minimum delay time of 10 min-

utes between rows to prevent panel overheating) until the required number of panel welds (190) per checkpoint interval are completed. These instructions apply to both the standard panel and the optional panel. The 190 panel-weld total allows for a total of 200 welds per endurance test interval when the five peel samples (ten welds) are included.

5.6 Surface Orientation (Coated Sheet Steels Only)

5.6.1 Peel-Test Samples. All peel-test samples shall be configured with the **marked side facing up**, as shown in Figure 9, and nesting the coupons as best as possible to prevent shear burrs on the coupon edges from contacting each other or the coupon surface.

5.6.2 Endurance Test Panel Samples

5.6.2.1 For sheet with nominally equal coating weight per side (e.g., 60G/60G), panel samples shall be

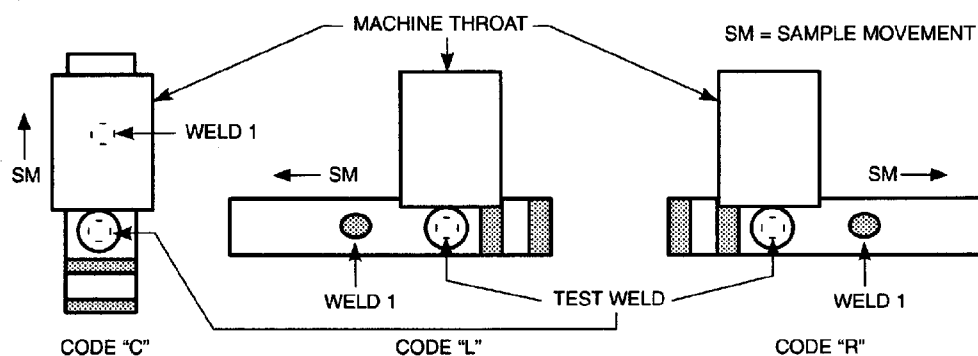


Figure 7—Top View of Peel Sample Orientations with Respect to Welding Machine Throat

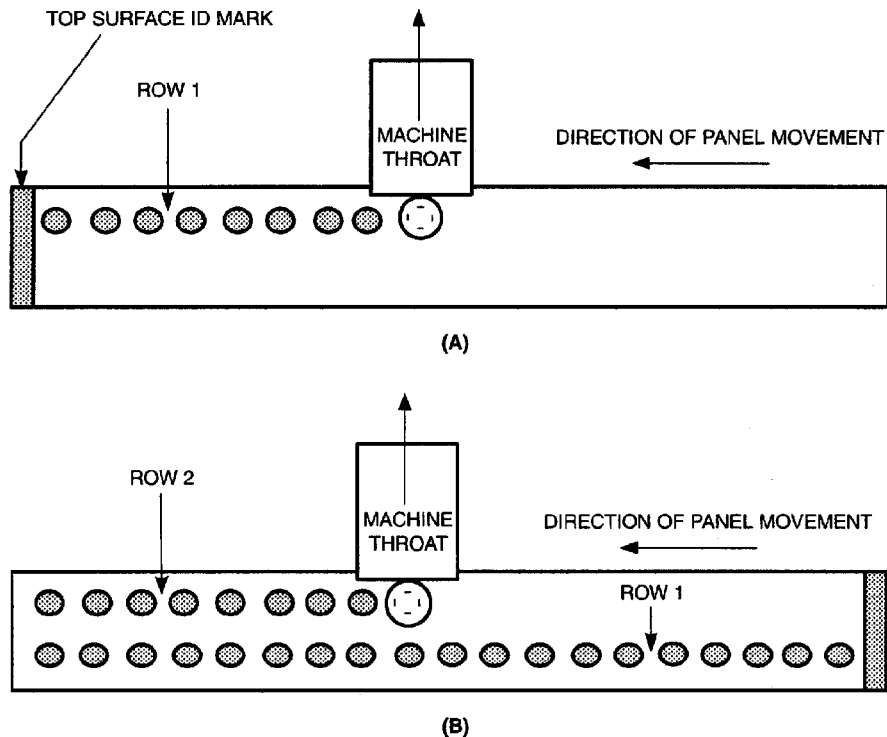


Figure 8—Panel Sample Orientations (A and B) with Respect to the Welding Machine Throat

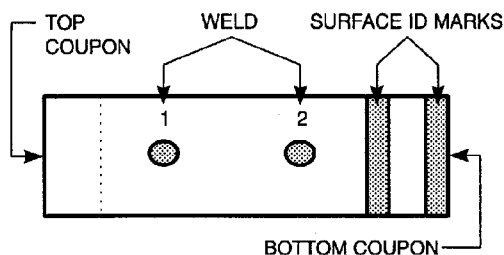


Figure 9—Surface Orientation of Peel-Test Samples

welded using the four surface-orientation combinations in the order specified in 1 through 4 below. This sequence shall be repeated on all subsequent panel sets (each group of four panels).

- (1) Top and bottom panel coupons both with the top surface ID mark facing up
- (2) Top and bottom panel coupons both with ID mark facing down
- (3) Top panel coupon with the ID mark facing up, bottom panel coupon with the ID mark facing down

- (4) Top panel coupon with the ID mark facing down, bottom panel coupon with the ID mark facing up

5.6.2.2 For differentially coated sheet (e.g., 60G/20G), panel samples shall be welded by alternating the surface-orientation combinations listed below. The marked side is the side with the heavier coating.

- (1) Top and bottom panel coupons both with the top surface ID mark facing up
- (2) Top and bottom panel coupons both with the top surface ID mark facing down

5.6.3 Weld Property Test Samples. All test samples (HTS panel, shear tension, and cross tension samples) shall be oriented with the marked side facing up, as shown in Figure 10. Overlap and weld spacings (HTS panel samples) are discussed and shown in the appropriate sections of the weld property test (section 10, Weld Property Tests).

5.7 Weld-Button Criteria

5.7.1 Minimum Weld Size (MWS). The minimum weld-button size is derived by the following formula:

$$\text{MWS} = 4\sqrt{t} \text{ or } 4 \times \text{square root of } t$$

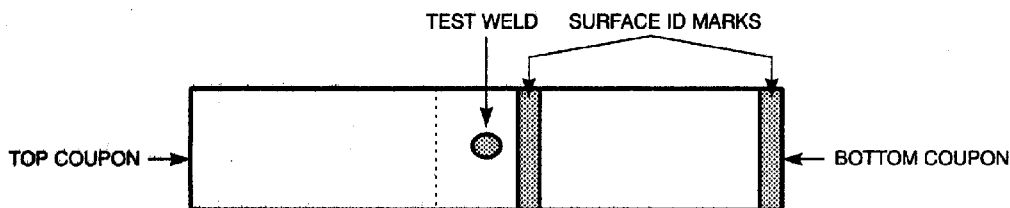


Figure 10—Surface Orientation of Weld Property Test Samples (Shear Tension Shown)

where t = avg. sheet thickness, rounded to the closest 0.01 mm, and
where MWS is rounded to the closest 0.1 mm.

5.7.2 Stabilization Weld Size (SWS). The stabilization weld-button size is derived by the following formula:

$SWS = 0.9 \times \text{specified electrode-face diameter}$
(dressed, listed in Table 3)

SWS is rounded to the closest 0.1 mm and has a target tolerance of ± 0.1 mm.

5.7.3 Face Diameter Weld Size (FDWS). The face diameter weld-button size is derived by the following formula:

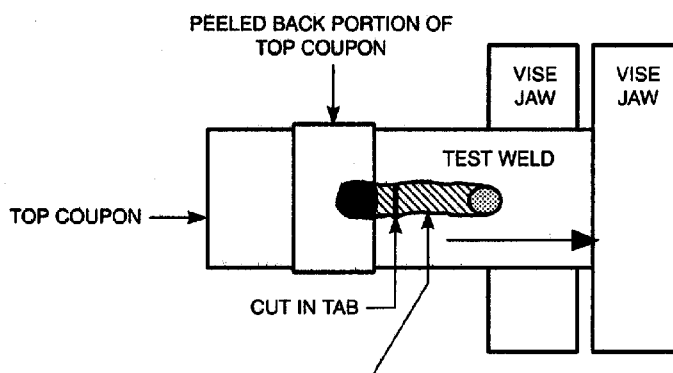
$FDWS = \text{the specified electrode-face diameter}$
(dressed, listed in Table 3)

FDWS is rounded to the closest 0.1 mm and has a tolerance of ± 0.2 mm.

5.7.4 Weld-Button Measurement. All weld buttons shall be measured across their minimum (D_{MIN}) and maximum (D_{MAX}) axes according to the pertinent rules stated in 5.7.4.1, 5.7.4.2, and 5.7.4.3 to the nearest 0.1 mm and shall be recorded. The mean of D_{MIN} and D_{MAX} shall be calculated to the nearest 0.1 mm and shall be recorded as the weld-button size. *Note: Where partial or full interfacial weld fractures occur, the minimum and maximum diameters of the fused area (FD_{MIN} and FD_{MAX}) shall also be measured to the nearest 0.1 mm and their mean calculated and recorded. (See 5.7.4.3.)*

5.7.4.1 To make proper measurements on peel-test samples, the tab that is usually pulled out of the base metal connecting the test and anchor welds is to be peeled back at 180 degrees to the original peeling direction. Sometimes this tab remains intact, requiring sawing or shearing to grip it. (See Figure 11.)

5.7.4.2 For crescent, oval, or other irregularly shaped buttons, button size shall be measured by rotating the knife caliper until D_{MIN} and D_{MAX} are located.



NOTE: THIS PORTION OF THE TAB SHALL BE PRIED UP AND PEELED BACK IN THE DIRECTION OF THE LARGE ARROW

Figure 11—Example of Tab Removal to Allow for Proper Measurement of Weld Buttons

Note: D_{MIN} and D_{MAX} are not necessarily perpendicular to each other. Care has to be taken that button lips (generally found perpendicular to the direction of peeling) are not included in the measurements. All measurements shall be as close as possible to the actual button perimeter. (See Figure 12A or Figure 12B.)

5.7.4.3 For partial interfacial fractures of weld buttons, both axes (minimum and maximum) of the weld button that is pulled and of the fused nugget area shall be measured. The button diameters are coded D_{MIN} and D_{MAX} while the fused area diameters are coded FD_{MIN} and FD_{MAX} (see Figure 13). When measuring the button diameters, all pertinent instructions in 5.7.4 apply to these measurements. *Note: For full interfacial fractures of weld buttons, no button measurements are possible, therefore only FD_{MIN} and FD_{MAX} can be measured.* When measuring the dimensions of the fused area (partial or full interfacial fracture mode), an optical magnification glass or some other suitable instrument may be required to determine the perimeter of the fused area.

5.7.5 Weld Fracture or Pullout Mode. The fracture or pullout mode (illustrated in Figure 14) of each test weld shall be determined and recorded for each test sample.

5.7.6 Acceptable Weld-Button Criteria. Both criteria (listed in 5.7.6.1 and 5.7.6.2) shall be met for welds at all I_{FDWS} , I_{MIN} , and I_{MAX} currents. For the endurance portion of the endurance test, only 5.7.6.1 applies.

5.7.6.1 Minimum Weld-Button Size. The test weld from the peel-test sample shall meet the minimum size criterion described in 5.7.1 to pass.

5.7.6.2 Weld-Button Fracture Mode. The test weld from the peel-test sample shall be of Type "RB" or "OB" (both exhibiting full perimeter fusion as determined by visual examination), shown in Figure 14, to pass (only applicable for current level determinations).

6. Preferred Test Equipment

This section lists the preferred test equipment to be used for all welding and testing. If equipment other than the preferred test equipment is used, specific note of this variance shall be made on the Welding Data Sheet and the appropriate test report. Recording of all pertinent test equipment is to be made on the appropriate data sheets or test reports.

6.1 Welding Machine

6.1.1 Type. A single point, single phase, 60 Hz, AC, 480 VAC (nominal), resistance spot welder with in-line loading and a pneumatic force application system shall

be used. Notation shall be made on the Welding Data Sheet and all test reports of the type of welder (pedestal, press, or gun) used for the test.

6.1.2 Capacities. The transformer has to be capable of producing the necessary secondary currents at percent heat/percent current settings of 60–92 percent, and which produces about a 100 ampere secondary current increment per each 1 percent heat/current setting increment. The force system shall be capable of providing the necessary welding forces without excessively harsh electrode impact (head velocity no greater than 80 mm/sec for a 50 kg head weight).

6.1.3 Controls. A microprocessor-based digital (electronic or thumb wheel) welding control, with SCR firing, and automatic voltage compensation (AVC) is required. The controller may be operated in a "constant voltage" mode (percent heat or percent current phase shift control) or a "constant current" mode (current programmed in amperes or kA). The type of controller mode to use is determined by agreement of the parties involved in the testing. The controller mode shall be recorded on the welding data sheet and all test reports. *Note: Potentiometer (dial)-type controllers shall not be used unless specific agreement of the parties involved in the testing is obtained.*

6.2 Current/Weld-Time Meter. An integrating-type current analyzer that measures effective (RMS) welding current and weld time shall be used.

6.3 Force Gage. A strain gage or piezo-electric type force gage with flat contact faces is required. The instrument shall be calibrated and have a minimum accuracy of ± 2 percent at the specific electrode force to be used.

6.4 Electrode Cooling. Appropriate flow meters, flow control devices, and temperature monitoring or control devices are needed to control/monitor electrode coolant. The machine cooling circuit shall be such that the coolant flowing to the electrodes shall not first flow through any other heat generating sources (e.g., SCRs or transformers). It is preferred that the electrodes are cooled in parallel, rather than in series, with respect to each other.

6.5 Weld Counter. Any electronic or mechanical device capable of sensing and counting each weld is acceptable. However, an electronic counter that senses welding current or some other signal that indicates a weld is made (current is passed) is highly recommended. *Note: When a mechanical counter is used, a lockout mechanism shall be used to prevent counting of non-welds when tip imprints are taken or when the welder is cycled without making a weld.*

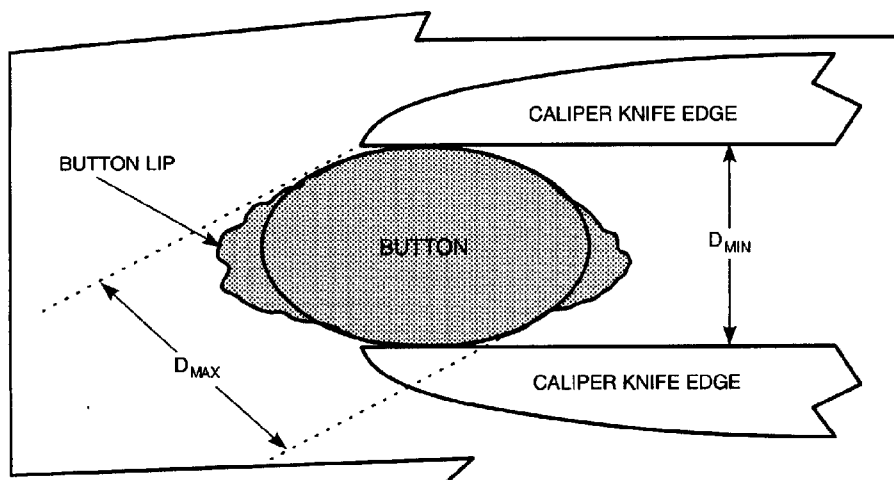


Figure 12A—Technique for Measuring Oval Weld Buttons

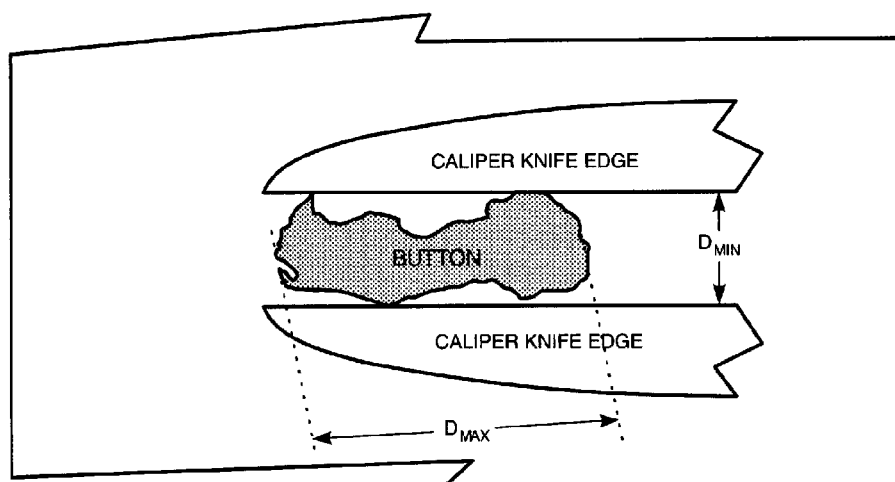


Figure 12B—Technique for Measuring Irregular Weld Buttons

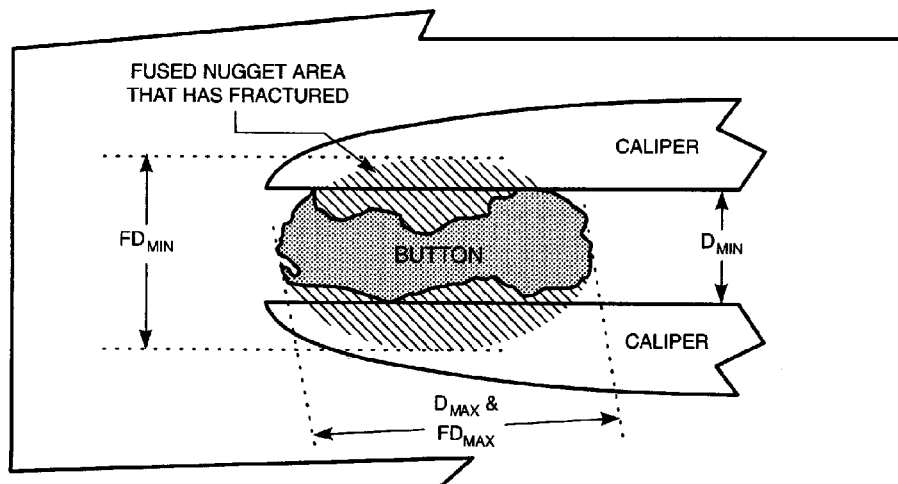


Figure 13—Technique for Measuring the Weld Button and Fused Diameters of Partial Interfacial Fractures

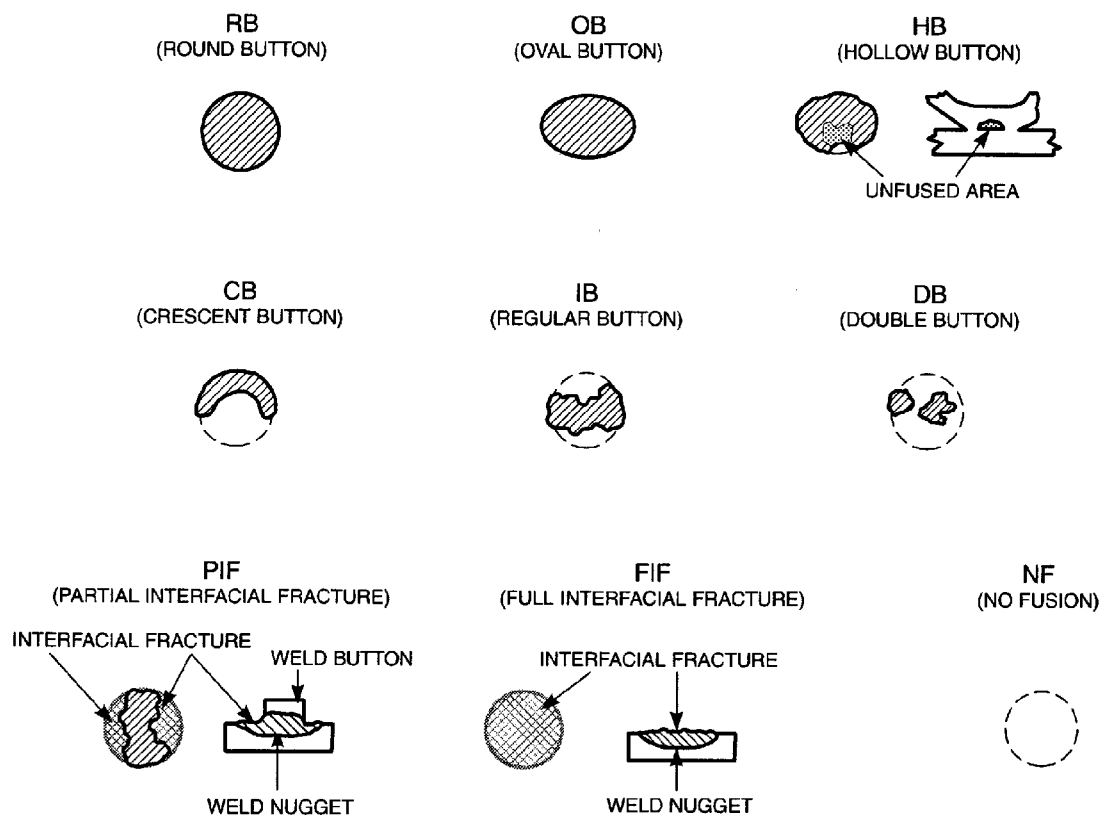


Figure 14—Fracture or Pullout Modes of Weld Buttons

6.6 Calipers. A knife-edge caliper capable of measuring to 0.01 mm is required for measuring weld-button dimensions.

6.7 Tip-Dressing File. A parallel, 150 mm long, extra smooth machinists file having a Swiss pattern, #2 cut is required for dressing and paralleling of the electrode faces.

6.8 Tip-Dressing Emery Paper. A 400 grit, silicon-carbide, A-weight emery paper may be used for final dressing of the electrode faces.

6.9 Carbon Paper. Premium quality carbon paper that produces sharp, dark electrode imprints shall be used to make all tip imprints.

6.10 Tip-Imprint Paper. High quality, smooth, white paper, such as used with laser printers or copiers, shall be used for all tip imprints.

6.11 Electrode Cooling Tubes

6.11.1 Dimensions. All cooling tubes shall have a pointed discharge end with a 45 degree angle. It is recommended that for electrode types 1 through 3, nominal cooling tube dimensions be 4.6 mm OD / 3.8 mm ID. For electrode types 4 and 5, nominal cooling tube dimensions shall be 6.4 mm OD / 4.8 mm ID. The type used shall be recorded on the Welding Data Sheet.

6.11.2 Position. The pointed end of the tube shall be in contact with the back-face (termination of the cooling hole) of the electrode (spring loaded or friction-fit sliding tubes are needed) as shown in Figure 15.

7. Electrode Installation and Dressing Procedure

7.1 Electrode Installation

7.1.1 Preparation. The appropriate electrodes shall be selected for the material being tested by consulting Table 3. Before installation of the electrodes (new or re-machined), the electrodes are to be coded T (for top) and B (for bottom), and both electrodes' face thicknesses (see Figure A1 of Annex A) shall be measured by an appropriate instrument. All electrodes have to be within ± 0.5 mm of the specified 9.7 mm face thickness. The face thicknesses for both electrodes (T and B) are to be recorded on the Welding Data Sheet. The electrodes' face diameters shall also be measured using any appropriate means that will provide accuracy to 0.05 mm. These measurements are to be coded T (for top diameter) and B (for bottom diameter), and shall be recorded on the Tip-Imprint Data Sheet.

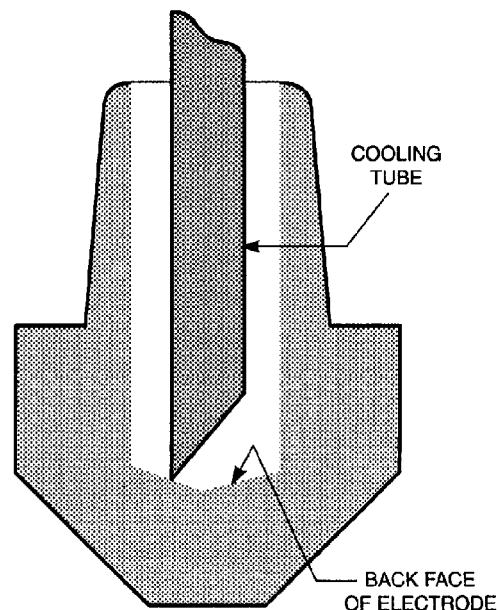


Figure 15—Required Position of Cooling Tubes in Electrodes

7.1.2 Installation Instructions. After the required measurements in 7.1.1 are complete, installation of the electrodes and appropriate may proceed. Before inserting the electrodes into the adapters/holders, the cooling tubes are to be adjusted to their proper position (see 5.3.3 or 6.11.2). The electrodes shall then be installed by inserting the electrodes into their adapters and applying adequate force (significantly lower than the target welding force) to seat them temporarily. This action is required to assure that the electrodes are in reasonably good alignment before final seating. When seated, the electrodes shall be checked for alignment.

7.1.2.1 If the electrodes are grossly misaligned, adjustments shall be made to achieve adequate alignment. When alignment has been achieved, the electrodes shall be fully seated by applying a welding force that is slightly greater than the force specified for the test.

7.1.2.2 If the electrodes are adequately aligned, the electrodes shall be fully seated by applying a welding force that is slightly greater than the force specified for the test. Final welding force adjustments shall be made later (see 7.1.5).

7.1.3 Gap Adjustment. The electrode holders shall be adjusted to provide the appropriate gap between the

electrodes (as required by the welding machine being used) or the proper airlock collapse distance (if the welder is so equipped).

7.1.4 Final Electrode Alignment. Final alignment of the electrodes shall be verified by bringing the electrodes together (with low or "tip dressing" force) and checking their alignment with a magnifying glass or some other suitable means. Adjustments shall be made to the electrode holders or other components, as needed, to achieve visual concentricity of the electrode faces.

7.1.5 Setting of the Welding Force. The welding force shall be set to its proper value using an appropriate force gage (see 6.3). If any adjustments to the air pressure are necessary to achieve the desired force, the machine should be cycled several times after each adjustment. The force shall be rechecked after each adjustment. *Note: It has to be ascertained that the force being measured is the force just prior to the onset of current flow (weld-time initiation) and that this force is not on a steep portion of the force buildup curve (applies to non-airlock systems only). Calibration of the force buildup curve is required for non-airlock systems to determine the amount of squeeze time necessary to reach force stability (near 98 percent of full static force).* After the final force adjustments are complete, the regulated air pressure setting for the cylinder applying the welding force shall be recorded.

7.2 Electrode Dressing

7.2.1 Tip Imprints of the Electrodes in the Undressed Condition. Before any electrode dressing is performed, duplicate sets of individual imprints (top and bottom electrodes) and of the composite imprint of the electrode faces shall be made in the boxes provided on the Tip-Imprint Data Sheet (or on a separate piece of paper if the imprints do not fit inside the boxes) using full electrode force. Figures 16A and 16B show the proper paper and electrode configurations for both types of imprints (individual and composite). These duplicate imprints shall be coded "UD-1" and "UD-2" (UD = undressed electrode).

7.2.2 Determining the Tip-Imprint Correction Factor (CF). The following procedure shall be used to ascertain the tip-imprint correction factor. *Note: All UD tip-imprint data is to be recorded on the Tip-Imprint Data Sheet.*

7.2.2.1 The maximum and minimum diameters for each UD tip imprint of the top electrode shall be measured. The mean for each imprint shall be calculated and the two means shall be labeled **TUD-1** and **TUD-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **TU**.

$$TU = (TUD-1 + TUD-2)/2$$

7.2.2.2 The maximum and minimum diameters for each UD tip imprint of the bottom electrode shall be measured. The mean for each imprint shall be calculated and the two means shall be labeled **BUD-1** and **BUD-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **BU**.

$$BU = (BUD-1 + BUD-2)/2$$

7.2.2.3 The tip-imprint correction factor for the top electrode (to be labeled **TCF**) shall be calculated by subtracting the measured mean diameter of the top electrode (**T**, obtained in 7.1.1), from the average of the two imprints for the top electrode (**TU**) as shown in the formula below.

$$TCF = TU - T$$

7.2.2.4 The tip-imprint correction factor for the bottom electrode (to be labeled **BCF**) shall be calculated by subtracting the measured mean diameter of the bottom electrode (**B**, obtained in 7.1.1), from the average of the two imprints for the bottom electrode (**BU**) as shown in the formula below.

$$BCF = BU - B$$

7.2.2.5 The mean tip-imprint correction factor (to be labeled **CF**) shall be calculated by the formula shown below.

$$CF = (TCF + BCF)/2$$

7.2.3 Paralleling and Sizing the Electrode Faces

7.2.3.1 If the electrode faces have been custom machined to the specified face diameter (within the proper tolerance) and it is known that the faces will be parallel when mounted in the electrode holders, it is permissible to proceed directly to step 7.2.11 using the composite tip print from step 7.2.1. Otherwise, the paralleling procedure and the electrode-face diameter adjustment instructions in the following steps shall be performed.

7.2.3.2 To parallel and size the electrode faces, the specified dressing file (see 6.7) is inserted between the tips, and the electrodes are brought together with low force/tip-dressing force (less than 50 kgF) so that both electrodes contact the file. The file is then rotated approximately 180 degrees in the horizontal plane, then back. After one back and forth rotation, the electrodes are retracted and the file cleaned of filings. This procedure should be repeated several times (typically two to four times) to achieve parallelism and the required face diameter.

7.2.3.3 To smooth the electrode faces after filing, a piece of emery paper may be folded over one piece of

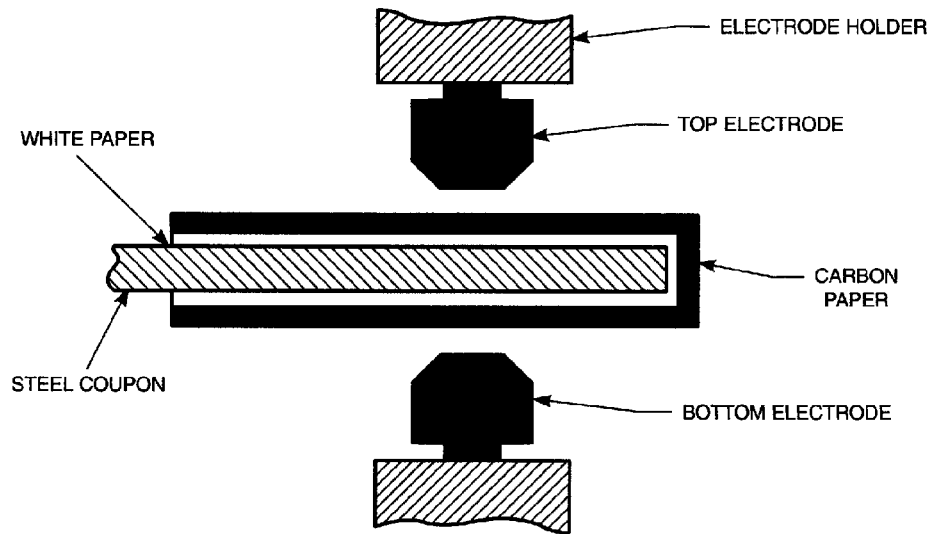


Figure 16A—Individual Tip-Imprint Schematic

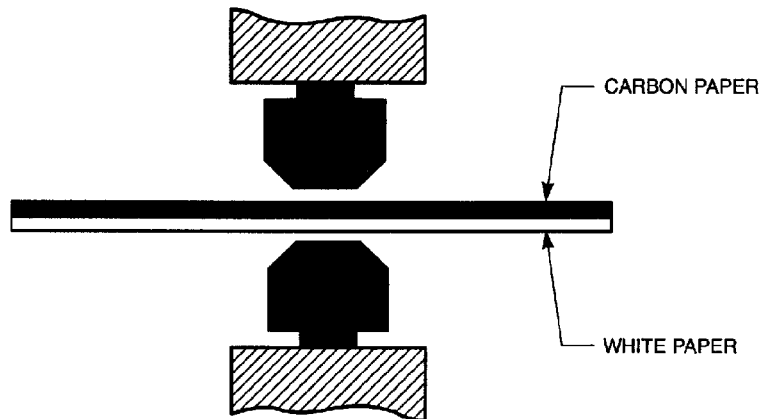


Figure 16B—Composite Tip-Imprint Schematic

flat, uncoated steel and may be inserted between the electrodes. The electrodes shall be brought together with low force/tip-dressing force (less than 50 kgF) so that both electrodes contact the emery cloth. The emery cloth can be rotated 180 degrees in the horizontal plane, then back. If necessary, this step may be repeated one time to smooth the electrode faces. *Note: If performed more than twice, face-edge rounding may occur which can result in erroneous tip-imprint measurements.*

7.2.4 Tip Imprints of the Electrodes after the First Dressing. After completion of 7.2.3.2 and 7.2.3.3, two individual and composite carbon imprints of the electrode faces (using full electrode force) shall be made in the boxes provided on the Tip-Imprint Data Sheet or on a separate piece of paper if the imprints do not fit inside the boxes. [See Figures 16A and 16B for paper and electrode configurations for both types of imprints (individual and composite)]. These duplicate imprints shall be coded **AD1-1** and **AD1-2** (AD1 = after dressing #1).

7.2.5 Determining the Electrode-Face Diameters after the First Dressing. The following procedure shall be used to ascertain the electrode-face diameters after the first dressing. *Note: All tip-imprint data shall be recorded on the Tip-Imprint Data Sheet.*

7.2.5.1 The maximum and minimum diameters for each AD1 tip imprint of the top electrode shall be measured. The mean for each imprint shall be calculated, and the two means shall be labeled **TAD1-1** and **TAD1-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **TD1**.

$$TD1 = (TAD1-1 + TAD1-2)/2$$

7.2.5.2 To calculate the correct electrode-face diameter for the top electrode, the imprint correction factor (CF from 7.2.2.5) shall be subtracted from **TD1**, as shown in the formula below. The result shall be labeled **TCD1** and shall be considered the correct electrode-face diameter of the top electrode after the first dressing.

$$TCD1 = TD1 - CF$$

7.2.5.3 The maximum and minimum diameters for each AD1 tip imprint of the bottom electrode shall be measured. The mean for each imprint shall be calculated, and the two means shall be labeled **BAD1-1** and **BAD1-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **BD1**.

$$BD1 = (BAD1-1 + BAD1-2)/2$$

7.2.5.4 To calculate the correct electrode-face diameter for the bottom electrode, the imprint correction factor (CF from 7.2.2.5) shall be subtracted from **BD1**, as shown in the formula below. The result shall be labeled **BCD1** and shall be considered the correct elec-

trode-face diameter of the top electrode after the first dressing.

$$BCD1 = BD1 - CF$$

7.2.6 Criteria for Additional Dressing or Dressing Termination. The TCD1 and BCD1 results shall be evaluated to determine which of the following criteria they meet.

7.2.6.1 If TCD1, BCD1, or both are below the tolerance (less than -0.1 mm) for the specified face diameter (e.g., 4.8 mm for a 5.0 mm face diameter), the electrode or electrodes not meeting this criterion shall be redressed by repeating steps 7.2.3.2 and 7.2.3.3, then proceeding to 7.2.7. *Note: If only one electrode requires additional dressing to achieve the desired face diameter, a smooth steel coupon shall be placed on the side of the file or emery cloth that faces the electrode not requiring further dressing.*

7.2.6.2 If TCD1 and BCD1 are within the tolerance (± 0.1 mm) for the specified face diameter, dressing is complete. Instructions continue in 7.2.10.

7.2.6.3 If TCD1, BCD1, or both are above the tolerance (greater than +0.1 mm) for the specified face diameter, a second set of electrodes shall be installed and Steps 7.1.1 through 7.2.6 repeated.

7.2.7 Tip Imprints of the Electrodes after the Second Dressing. After completion of 7.2.3.2 and 7.2.3.3, two individual and composite carbon imprints of the electrode-faces (using full electrode force) shall be made in the boxes provided on the Tip-Imprint Data Sheet or on a separate piece of paper if the imprints do not fit inside the boxes. [See Figures 16A and 16B for paper and electrode configurations for both types of imprints (individual and composite)]. These duplicate imprints shall be coded **AD2-1** and **AD2-2** (AD2 = after dressing #2).

7.2.8 Determining the Electrode-Face Diameters after the Second Dressing. The following procedure shall be used to ascertain the electrode-face diameters after the second dressing. *Note: All tip-imprint data shall be recorded on the Tip-Imprint Data Sheet.*

7.2.8.1 The maximum and minimum diameters for each AD2 tip-imprint of the top electrode shall be measured. The mean for each imprint shall be calculated and the two means shall be labeled **TAD2-1** and **TAD2-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **TD2**.

$$TD2 = (TAD2-1 + TAD2-2)/2$$

7.2.8.2 To calculate the correct electrode-face diameter for the top electrode, the imprint correction factor (CF from 7.2.2.5) shall be subtracted from **TD2**, as

shown in the formula below. The result shall be labeled **TCD2** and shall be considered the correct electrode-face diameter of the top electrode after the second dressing.

$$\text{TCD2} = \text{TD2} - \text{CF}$$

7.2.8.3 The maximum and minimum diameters for each AD2 tip imprint of the bottom electrode shall be measured. The mean for each imprint shall be calculated and the two means shall be labeled **BAD2-1** and **BAD2-2**. The average of the two imprints shall be calculated as shown in the formula below, and shall be labeled **BD2**.

$$\text{BD2} = (\text{BAD2-1} + \text{BAD2-2})/2$$

7.2.8.4 To calculate the correct electrode-face diameter for the bottom electrode, the imprint correction factor (CF from 7.2.2.5) shall be subtracted from **BD2**, as shown in the formula below. The result shall be labeled **BCD2** and shall be considered the correct electrode-face diameter of the bottom electrode after the second dressing.

$$\text{BCD2} = \text{BD2} - \text{CF}$$

7.2.9 Criteria for Completion of Dressing or for the Need to Install New Electrodes. The TCD2 and BCD2 results shall be evaluated to determine which of the following criteria they meet.

7.2.9.1 If TCD2 and BCD2 are within the tolerance (± 0.1 mm) for the specified face diameter, dressing is complete. Instructions continue at step 7.2.10.

7.2.9.2 If TCD2, BCD2, or both are above or below the tolerance (± 0.1 mm) for the specified face diameter (e.g., 5.2 mm or 4.8 mm for a 5.0 mm face diameter) after this second dressing, a second set of electrodes shall be installed and dressed by repeating steps 7.1.1 through 7.2.6 (or through 7.2.9 if a second dressing is necessary). The electrodes are not to be redressed for size after the second dressing. If the tolerances cannot be achieved after the second dressing of the second set of electrodes, the instructions in 7.2.12 shall be followed next.

7.2.10 Parallelism and Concentricity Check of the Electrode Faces. To verify electrode-face concentricity and parallelism, the **composite** tip imprints obtained after the latest dressing (step 7.2.3.1, 7.2.4 or 7.2.7) shall be measured. The measurements shall be recorded on the Tip-Imprint Data Sheet. If the difference between the major and minor diameters of the imprints is greater than 0.1 mm, several more composite imprints shall be made to be sure that the carbon paper or white paper is not the cause of the apparent lack of concentricity. These imprints shall also be measured and examined closely. If the difference between the major and minor diameters is still greater than 0.1 mm, the electrode-face alignment

has to be carefully rechecked with a magnifying glass or some other suitable instrument when both electrodes are in contact with each other (head down). A back-light may help in this visual examination. Alignment shall be checked at several locations approximately 90 degrees apart, and the appropriate actions described in 7.2.10.1 or 7.2.10.2 shall be taken.

7.2.10.1 If misalignment is evident, adjustments to achieve alignment shall be made. After each adjustment, the alignment should be visually checked (as in 7.2.10), and additional composite tip imprints shall be made and measured. If alignment is visually acceptable yet the tip imprints do not meet the concentricity tolerance (0.1 mm), instructions continue in 7.2.10.2. If the tip imprints meet the concentricity tolerance, instructions continue in 7.2.10.3.

7.2.10.2 The electrodes shall be redressed **very lightly** as in steps 7.2.3.2 and 7.2.3.3, being certain that no rounding of the electrode face occurs. Several more composite and individual tip imprints shall be made and measured after redressing. If the electrodes meet the concentricity tolerance and both are still within the maximum size tolerance ($+0.1$ mm), instructions continue in 7.2.10.3. If the electrodes do not meet the concentricity tolerance or one or both are above the maximum size tolerance ($+0.1$ mm), a second set of electrodes shall be installed, following the installation procedure described in steps 7.1.1 through 7.2.10. If the tolerances cannot be achieved with the second set of electrodes, the instructions in 7.2.12 shall apply immediately.

7.2.10.3 The latest set of composite tip imprints shall be examined for uniformity of shading (indicating parallelism). The imprints shall show relatively uniform darkness from edge to edge. If gross differences in shading are observed on all imprints, the electrodes have to be redressed (if they have not been dressed twice, excluding the dressing in 7.2.10.2) using steps 7.2.3.2, 7.2.3.3, and 7.2.7 through 7.2.10, or a second set of electrodes has to be installed (steps 7.1.1 through 7.2.10) if the first set of electrodes had been dressed twice. If the tolerances cannot be achieved with the second set of electrodes, the instructions in 7.2.12 shall apply immediately.

7.2.11 Weld Heat-Pattern Alignment and Parallelism Check. Several "heat-pattern welds" shall be made on one piece of clean, flat, uncoated steel (about 0.8 mm thick) using a low-current setting (about 6–7 kA), being sure that the electrode coolant is flowing when making these "welds." The heat pattern around the "welds" should be relatively circular and uniform if the electrode faces are parallel and aligned. If gross irregularities in the heat pattern are evident, the electrodes have to be redressed (if they have not been dressed twice, excluding

the dressing in 7.2.10.2) using the redressing instructions (steps 7.2.3.2, 7.2.3.3, and 7.2.7 through 7.2.11), or a second set of electrodes has to be installed (as described in steps 7.1.1 through 7.2.11) if the first set of electrodes had been dressed twice. If the same results are obtained with the second set of electrodes, the instructions in 7.2.12 shall apply.

7.2.12 If the installation, second dressing, and other adjustments of a second set of electrodes still do not meet the stated tolerances or other criteria stipulated in the foregoing steps, **a third set of electrodes shall not be installed.** The second set of electrodes shall then be used even though the tolerances or criteria were not met. The specific tolerances or criteria that were not met shall be noted on the Tip-Imprint Sheet, the Welding Data Sheet, and the Test Report.

8. Electrode-Face and Weld-Size Stabilization Procedure

8.1 Introduction and Overview. To compensate for the dynamic behavior of welding current versus weld size that occurs when making welds with new electrodes, especially when welding coated steels, a weld size stabilization procedure shall be performed at the start of any test. This stabilization procedure "conditions" the electrode faces, thus stabilizing the weld size behavior and promoting reproducibility of test results. In summary,

this stabilization procedure consists of adjusting the welding current as needed to maintain a specified/fixed weld size. Figure 17 shows a graph that depicts typical steps of the stabilization procedure.

Depending upon the test material, welding conditions, and weld size behavior, the stabilization procedure may require from approximately 80 to 250 (maximum allowed) welds. Except as specifically indicated, the welding conditions, parameters, materials, panel welding sequence, etc. used in this stabilization procedure shall be the same as those that will be used in the subsequent test procedure. In all cases, only the "test" weld (2nd weld) of the peel sample is used for establishing button size and fracture mode. The target weld-button size during the stabilization procedure is termed the *stabilization weld size (SWS)* and is defined as 90 percent of the dressed face diameter listed in Table 3 (e.g., SWS = 4.5 mm for a 5.0 mm dressed face diameter). The SWS is rounded to the closest 0.1 mm.

8.2 Preparation

8.2.1 Before proceeding, an adequate quantity of peel-test and panel coupons required for this procedure shall be prepared, following the instructions in section 3, Sample Preparation. The appropriate welding parameters shall be determined for the material being tested by consulting Table 3. All welding parameters shall be set according to section 5, Welding Parameters, for the material being tested.

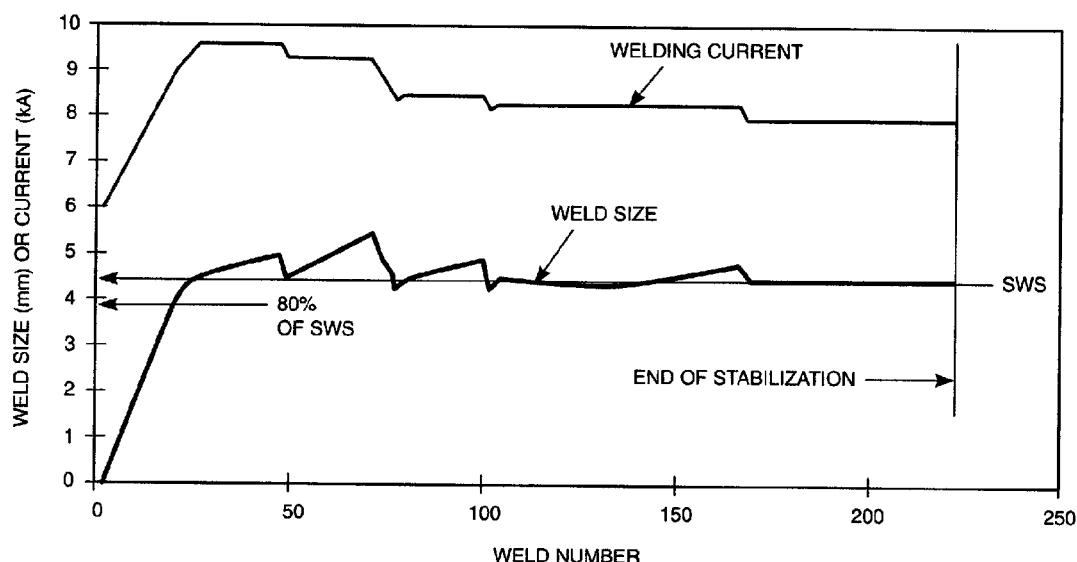


Figure 17—Graphical Example of a Typical Stabilization Procedure

8.2.2 The following items shall be recorded on the Welding Data Sheet:

- (1) A test code
- (2) The type of test (Endurance Test, Weld Property Test etc.)
- (3) All pertinent material data that is requested on the data sheet
- (4) The laboratory name and address
- (5) The date (or dates if run over one day) of the test
- (6) The name of the test operator
- (7) All welding parameters and electrode data

8.2.3 The following items shall be checked before proceeding:

(1) The electrodes have been properly dressed and that tip prints have been made, measured and recorded on the Tip-Imprint Data Sheet.

(2) The electrode coolant flow is on and at the proper flow setting and temperature (actual flow and temperature shall be recorded on the Welding Data Sheet)

(3) The weld counter is reset to zero

8.2.4 For all test samples that are welded and tested, the following shall be recorded:

- (1) The tap and current setting (percent heat/percent current or programmed current) of each test weld
- (2) The measured welding current of each test weld (not anchor or panel welds)
- (3) The expulsion (E) or non-expulsion (NE) of each weld (both welds in peel-test samples)
- (4) The peel-test sample orientation
- (5) D_{MIN} , D_{MAX} , the mean weld-button size, and the button fracture mode of each test weld [FD_{MIN} , FD_{MAX} (the dimensions of the fused area), and their mean shall also be recorded for any partial or full interfacial fractures (PIF and FIF)]

8.3 Stabilization Procedure

8.3.1 Based on test data previously obtained for the type of material being evaluated, the welding current shall initially be set to a value that should result in a "no-fusion" condition (approximately 1000 amperes less than the current required to produce a minimum size weld). If previous data is unavailable, the appropriate default welding current presented in Table 6 may be used for the starting point.

8.3.2 One peel-test sample shall be welded and tested at this initial current setting. *Note: All peel-test samples used in the stabilization procedure shall be coded with the prefix S and their orientation kept constant, i.e., all type C, all type L, or all type R (see Figure 7).*

8.3.2.1 If the test weld exhibits a no-fusion condition (no weld nugget nor button), step 8.3.3 follows.

Table 6
Default Initial Welding Currents

Sheet Thickness (mm)	Current (kA)		
	Uncoated	Zn Alloy Coated	Zn Coated
0.60-0.69	4 to 5	5	5 to 6
0.70-0.89	5 to 6	6	6 to 7
0.90-1.29	6 to 7	7 to 8	8 to 9
1.30-1.69	8 to 9	9	9 to 10
1.70-2.09	10 to 11	11 to 12	12 to 13

Note: Listed values are for low-strength products. For materials with minimum yield strengths less than 275 MPa, listed values should be reduced by approximately 1 kA.

8.3.2.2 If a weld button of any size is obtained, the current setting is to be lowered in increments of 1000 amperes. One peel-test sample shall be welded and tested at each increment until a no-fusion condition is obtained. After this condition is met, step 8.3.3 follows.

8.3.3 The current setting shall be increased in increments of approximately 300 A. One peel-test sample is to be welded and tested at each increment until the weld-button size is approximately 70 to 80 percent of the SWS (for a 5.0 mm electrode face, SWS = 4.5 mm, and 80 percent of 4.5 mm = 3.6 mm.). After this condition is met, step 8.3.4 follows.

8.3.4 The current setting shall then be increased in smaller increments of approximately 100 A. Two peel-test samples shall be welded and tested at each increment until the average weld-button size for the two samples meets the SWS (within ± 0.1 mm) or slightly exceeds it. *Note: If the last set of peel-test samples produces an average button size that is greater than the 0.1 mm tolerance of the SWS (e.g., 4.7 mm for an SWS of 4.5 mm), the current setting may not be reduced in an attempt to reach the SWS. Once the SWS has been reached or exceeded by one pair of peel-test samples in this initial determination of the SWS current, no reduction in current is allowed. After the conditions in this step are met, step 8.3.5 follows.*

8.3.5 The current shall be adjusted to the setting (from step 8.3.4) that produced an average weld-button size that meets or is closest to the SWS without exceeding the ± 0.1 mm tolerance (e.g., if SWS = 4.5 mm, and the 80 percent current setting = 4.2 mm and the 81 percent current setting = 4.7 mm, the current is to be set to 80 percent). Step 8.3.6 follows.

8.3.6 At the most recently determined current setting (from step 8.3.5 for the initial loop and from step 8.3.7.1

or 8.3.7.4 for subsequent loops), one row of 19 welds shall be made on a panel sample with the specified weld spacing and welding rate. The surface orientation(s) of the panel shall be as follows:

(1) For equally coated sheet (e.g., 60G/60G), the entire row shall be welded with the marked side of both the top and bottom coupons facing up (Surface Orientation 1).

(2) For differentially coated sheet (e.g., 60G/20G), welding shall be performed with the marked side of both coupons facing up (Surface Orientation 1) for 10 welds, then flipping the panel upside down so that the marked sides are down (Surface Orientation 2) for the remaining 9 welds.

8.3.6.1 If any expulsion or severe electrode sticking occurs on these panel welds, welding shall be **halted immediately**. The current shall then be reduced in increments of approximately 300 A. Two peel-test samples shall be welded and tested at each increment until the average weld-button size for the two samples is less than the average weld size determined for the most recent loop (step 8.3.5 or 8.3.7.4). After this current reduction sequence has been completed, step 8.3.7.3 follows directly.

8.3.6.2 If all 19 welds were successfully completed, step 8.3.7 follows.

8.3.7 Without adjusting the current setting, two peel-test samples shall be welded. If no expulsion occurs on any of the four welds, the samples shall be tested and their weld sizes measured. The condition that applies shall then be determined (8.3.7.1, 8.3.7.2, or 8.3.7.3), and instructions for that condition shall be followed.

Note: If expulsion occurs on any of the four welds (anchor or test), welding is to be halted immediately. The current shall then be reduced in increments of approximately 300 A until a no-expulsion condition is achieved by all four welds of the two samples. Once this is achieved, the samples shall be tested and their weld sizes measured. The condition that applies shall then be determined (8.3.7.1, 8.3.7.2, or 8.3.7.3), and instructions for that condition shall be followed. (Any samples that contain expulsion welds do not need to be tested.)

8.3.7.1 If the mean button diameter is equal to or greater than the average weld size determined for the most recent loop (step 8.3.5 or 8.3.7.4) and is not larger than SWS + 0.1 mm, the current setting shall not be adjusted, and step 8.2.8 shall be consulted to determine the status of the stabilization process.

8.3.7.2 If the mean button diameter is greater than SWS + 0.1 mm, the current shall be reduced in increments of approximately 300 A. Two peel-test samples shall be welded and tested at each increment until the av-

erage weld-button size for the two samples is less than the average weld size determined for the most recent loop (step 8.3.5 or 8.3.7.4). Once this condition is met, step 8.3.7.3 follows.

8.3.7.3 If the mean button diameter is less than the average weld size determined for the most recent loop (step 8.3.5 or 8.3.7.4), the current setting shall be increased in increments of approximately 100 A. Two peel-test samples shall be welded at each increment until the average weld-button size for the two samples meets the SWS (within ± 0.1 mm) or slightly exceeds it. Once this condition is met, step 8.3.7.4 follows.

8.3.7.4 The welding current shall be adjusted to the setting from step 8.3.7.3 that produced an average weld-button size (of the two test welds) that meets or is closest to the SWS without exceeding the +0.1 mm tolerance (e.g., if SWS = 4.5 mm, and the 80 percent current setting = 4.2 mm and the 81 percent current setting = 4.7 mm, the current shall be set to 80 percent). *Note: If this current setting is the same as that used for the most recent loop (this is improbable but not impossible), the loop is to be considered successfully completed without a change in current settings.* The status of the stabilization process is to be established at this point by proceeding to step 8.3.8 before further welding is performed.

8.3.8 If any one of the conditions listed in 8.3.8.1 through 8.3.8.3 for ending the stabilization procedure has been met, the stabilization process is complete. If none are met, the process loops back to step 8.3.6, and steps 8.3.6 through 8.3.8 (with the latest current settings from either step 8.3.7.1 or 8.3.7.4) shall be repeated until any of the following conditions for ending the stabilization procedure are met.

8.3.8.1 It has been determined that the current required to meet the SWS has remained unchanged and remains stable (within about ± 100 A peel-test welds only) in three consecutive cycles or loops. Each loop consists of steps 8.3.6 through 8.3.8, ends at the conditional phrase at the start of step 8.3.8, and requires 23 welds (19 panel welds and 4 peel-test welds) all at the same current setting.

8.3.8.2 It has been determined that the current required to meet the SWS has increased by 300 A or more over the initial current required to achieve the SWS in step 8.3.5. *Note: This condition mainly applies when welding on highly aggressive coatings (regarding electrode wear).*

8.3.8.3 It has been determined that a total of 250 welds has been made during the stabilization procedure (total includes all welds made on peel and panel samples).

8.3.9 After any one of the conditions in 8.3.8 has been met, two sets of individual and two sets of composite carbon imprints of the electrode tips shall be made, and the number of welds made during the electrode stabilization process shall be recorded. Upon successful completion of the electrode stabilization procedure, the desired tests may begin.

9. Endurance Test

9.1 Introduction and Overview. The endurance test procedure is primarily designed to assess spot weldability of coated sheet steel using several criteria, however, it may also be suitable for evaluating other materials. The criteria used in this test provide significant information about several aspects of spot welding behavior of sheet materials. The criteria include Initial I_{MIN} (II_{MIN}) and Initial I_{MAX} (II_{MAX}) welding currents and current range (immediately following the stabilization procedure), the endurance limit (number of welds until the test termination criterion is met), and Final I_{MIN} (FI_{MIN}) and Final I_{MAX} (FI_{MAX}) welding currents and current range (immediately following the endurance portion). Figure 18 is a

graphical example of the results obtained with the endurance test method.

9.2 Test Preparation. After the stabilization procedure (section 8, Electrode Face and Weld-Size Stabilization Procedure) is completed, the weld counter is to be reset to zero, and it shall be confirmed that all welding parameters are still at their specified values. All pertinent information shall be entered on the Welding Data Sheet if this has not yet been done. As welds are made and tested, all required data (see 8.2.1 & 8.2.2) shall be recorded. All peel tests' surface orientation (see 5.6 and Figure 9) shall be kept constant throughout the test. Also, the minimum weld-button size (MWS) is to be calculated for the sheet thickness being tested using the formula found in 5.7.1, and shall be recorded.

9.3 Initial I_{MIN} Current Determination. *Note: All peel-test samples welded during the determination of the Initial I_{MIN} and I_{MAX} currents (9.3 & 9.4) of the test shall be coded with the prefix "ICL."*

9.3.1 Based on weld size and welding current data from the weld stabilization procedure (Section 8), the current setting shall be adjusted low enough to produce a weld that is at least 0.5 mm smaller than the MWS (ide-

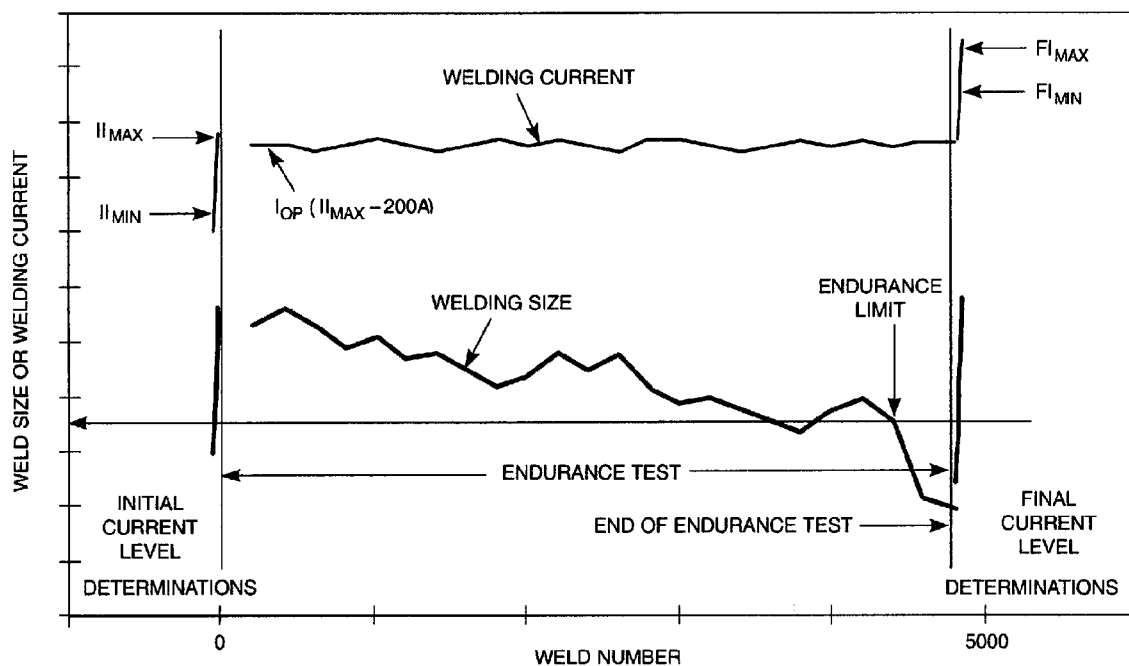


Figure 18—Graphical Example of the Endurance Test Procedure

ally 0.5 to 1.0 mm smaller than the MWS). One peel-test sample shall be welded and tested at this current. If the resulting weld button is:

- (1) smaller than MWS—0.5 mm, step 9.3.2 follows.
- (2) larger than MWS—0.5 mm (e.g., larger than 3.1 mm for an MWS of 3.6), the current shall be reduced in increments of 300 A, and one peel-test sample shall be welded and tested at each increment until the weld-button size is smaller than MWS – 0.5 mm. When this condition has been met, step 9.3.2 follows.

9.3.2 The current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample (any orientation type) shall be welded and tested until a weld button is obtained that satisfies both the MWS and the fracture-mode requirements (see 5.7.6) for I_{MIN} . *Note: After both I_{MIN} criteria have been met by a peel-test sample, a reduction in current is never allowed even though the button diameter may be greater than the minimum.* The orientation type [C, L, or R (see Figure 5.5.1)] of the first peel sample that meets both I_{MIN} criteria shall be recorded.

9.3.3 Using both of the other two sample orientation types not used in step 9.3.2 (i.e., if orientation C was used in step 9.3.2, L and R shall be used in this step), two peel-test samples shall be welded and tested at the same I_{MIN} current setting found in step 9.3.2.

9.3.3.1 If both of these samples meet the I_{MIN} criteria, step 9.3.4 follows.

9.3.3.2 If either of these samples does not satisfy the I_{MIN} criteria, the current setting shall be increased in increments of approximately 100 A, and peel-test samples shall be welded and tested until samples of all three orientations (all welded consecutively at the same current setting) meet the I_{MIN} criteria. After this criterion is met, step 9.3.4 follows.

9.3.4 The Initial I_{MIN} shall be calculated (in kA rounded to the nearest 0.1 kA) by averaging the current (recorded to 0.1 kA) measured for the test welds (second weld) from the final three peel-test samples in steps 9.3.2 and 9.3.3.1 or step 9.3.3.2. The average of the measured currents for these samples is the Initial I_{MIN} current. This current shall be coded II_{MIN} and be recorded on the Welding Data Sheet.

9.3.5 The average weld-button size shall be calculated (rounded to the closest 0.1 mm) for the three peel samples mentioned in 9.3.4. This mean weld size is the Initial I_{MIN} button diameter. The mean shall be coded ID_{MIN} and be recorded on the Welding Data Sheet.

9.4 Initial I_{MAX} Current Determination

9.4.1 Starting from the Initial I_{MIN} current established in 9.3, the current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample shall be welded and tested until either of the two I_{MAX} criteria [expulsion (interfacial) or severe electrode-to-sheet sticking for both welds of the peel sample] is met. *Note: At each increment, the peel sample orientation is to be changed so that the three types of peel samples are sequentially used (e.g., "C", then "L", then "R", then "C", etc.).* The orientation type (C, L, or R [see Figure 5.5.1]) of all peel-test samples shall be recorded. Once one sample meets either of the I_{MAX} criteria, welding shall cease immediately.

9.4.2 The current measured for the test weld (second weld) of the last sample (the one that meets either of the two I_{MAX} criteria) is the Initial I_{MAX} current. This current shall be coded II_{MAX} . The weld button diameter of this weld shall be coded ID_{MAX} . Both II_{MAX} and ID_{MAX} shall be recorded on the Welding Data Sheet.

9.4.3 After II_{MAX} has been determined, duplicate individual and composite carbon tip imprints of the electrode faces shall be made on the Tip-Imprint Data Sheet or some other suitable paper.

9.4.4 The total number of welds (one peel sample = two welds) made in 9.3 and 9.4 shall be recorded on the Welding Data Sheet, being certain not to count any imprint strokes or other non-weld strokes as welds when a mechanical weld counter is used. The weld counter shall then be reset to zero.

9.5 Endurance Test. See Figure 18 for an example of typical results.

9.5.1 Based on the II_{MAX} current obtained in 9.4.2, the current setting shall be adjusted so that the expected welding current will be as close as possible to 200 A below the II_{MAX} current. This current is the operating current and is to be labeled I_{OP} . I_{OP} shall be kept constant throughout the endurance test.

9.5.2 Using a sufficient number of panel samples (see 5.6.2 for surface orientations and 5.5.3 for panel sequencing), 190 consecutive panel welds shall be made. The specified weld spacing (see Table 5) and panel welding rate (see Table 3) for the material being tested shall be used for all panel welds.

9.5.3 After completion of the 190 panel welds, five peel-test samples shall be welded and tested. All three peel-test sample orientations are to be used in this set of five samples, with no orientation being used for more than two samples. The order of welding the different peel-test sample orientations (C, L, and R) shall be ran-

domized at each 200-weld checkpoint (e.g., at checkpoint 200, the sequence might be C, L, R, L, C; at checkpoint 400, the sequence might be L, C, R, R, C; etc.). Each set of peel samples is designated as the "200 welds" data set. *Note: All peel-test samples welded during this portion of the test shall be coded only with the test weld number (e.g., 192, 194, 196, etc.).* The average weld-button size and average welding current shall be calculated for the five peel-test samples at each 200-weld checkpoint. The means shall be recorded on the Welding Data Sheet.

9.5.4 After completion of the peel-test welds at each checkpoint, duplicate individual and composite carbon tip imprints of the electrode face shall be made on the Tip-Imprint Data Sheet or some other suitable paper. All tip imprints in this section are coded by using the weld number of the peel test most recently welded. When a mechanical weld counter is used, the counter is to be locked out for taking tip imprints so that no imprint strokes are counted as welds.

9.5.5 Steps 9.5.2 through 9.5.4 shall be repeated in sequential order until the test termination criterion is reached. The test termination point is reached when the weld-button size of all five peel-test samples is below the minimum weld-button size for two consecutive 200-weld checkpoints.

9.6 Final I_{MIN} Current Determination. *Note: All peel-test samples welded during the determination of the Final I_{MIN} and I_{MAX} currents (9.6 and 9.7) shall be coded with the prefix FCL.*

9.6.1 Starting from the operating current (I_{OP} used in 9.5), the current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample (any orientation type) shall be welded and tested until a weld button is obtained that satisfies both the MWS and the fracture-mode requirements (see 5.7) for I_{MIN} . *Note: After both I_{MIN} criteria have been met by a peel-test sample, a reduction in current is never allowed even though the button diameter may be greater than the minimum.* The orientation type [C, L, or R (see Figure 5.5.1)] of the first peel-test sample that meets both I_{MIN} criteria shall be recorded.

9.6.2 Using both of the other two sample orientation types not used in step 9.6.1 (i.e., if orientation C was used in step 9.6.1, L and R shall be used in this step), two peel-test samples shall be welded and tested at the same I_{MIN} current setting found in step 9.6.1.

9.6.2.1 If both of these samples meet the I_{MIN} criteria, step 9.6.3 follows.

9.6.2.2 If either of these samples does not satisfy the I_{MIN} criteria, the current setting shall be increased in

increments of approximately 100 A, and peel-test samples shall be welded and tested until samples of all three orientations (all welded consecutively at the same current setting) meet the I_{MIN} criteria. After this criterion is met, step 9.6.3 follows.

9.6.3 The Final I_{MIN} shall be calculated (in kA rounded to the nearest 0.1 kA) by averaging the current (recorded to 0.1 kA) measured for the test welds (second weld) from the final three peel-test samples in steps 9.6.1 and 9.6.2.1 or step 9.6.6.2. The average of the measured currents for these samples is the Final I_{MIN} current. This current shall be coded FI_{MIN} and be recorded on the Welding Data Sheet.

9.6.4 The average weld-button size shall be calculated (rounded to the closest 0.1 mm) for the three peel samples mentioned in 9.6.3. This mean weld size is the Final I_{MIN} button diameter. The mean shall be coded ID_{MIN} and be recorded on the Welding Data Sheet.

9.7 Final I_{MAX} Current Determination

9.7.1 Starting from the Final I_{MIN} current established in 9.6, the current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample shall be welded and tested until either of the two I_{MAX} criteria [expulsion (interfacial) or severe electrode-to-sheet sticking for both welds of the peel sample] is met. *Note: At each increment, the peel sample orientation is to be changed so that the three types of peel samples are sequentially used (e.g., "C", then "L", then "R", then "C", etc.).* The orientation type [C, L, or R (see Figure 5.5.1)] of all peel-test samples shall be recorded. Once one sample meets either of the I_{MAX} criteria, welding shall cease immediately.

9.7.2 The current measured for the test weld (second weld) of the last sample (the one that meets either of the two I_{MAX} criteria) is the Final I_{MAX} current. This current shall be coded FI_{MAX} . The weld-button diameter of this weld shall be coded FD_{MAX} . Both FI_{MAX} and FD_{MAX} shall be recorded on the Welding Data Sheet.

9.7.3 After FI_{MAX} has been determined, duplicate individual and composite carbon tip imprints of the electrode faces shall be made on the Tip-Imprint Data Sheet or some other suitable paper.

9.7.4 The total number of welds (one peel sample = two welds) made in 9.6 and 9.7 shall be recorded on the Welding Data Sheet, being certain not to count any imprint strokes or other nonweld strokes as welds when a mechanical weld counter is used.

9.8 Replication. The entire test shall be repeated at least once (for a total of 2 sets of test results) or for as many additional replications as desired. For each replication,

returning to section 7 and completing sections 7 through 9 is required.

9.9 Calculations for Mean Current Levels and Current Ranges

9.9.1 Calculation of ICR. Calculation for the Initial Current Range (coded ICR) shall be performed for each replication using the following formula:

$$ICR = II_{MAX} - II_{MIN}$$

9.9.2 Calculation of Mean II_{MIN} , Mean II_{MAX} , and Mean ICR. Calculation for the means of all "Initial" current levels and current ranges for all replications (coded R1, R2, etc.) shall be performed using the following formulas:

(1) Mean $II_{MIN} = (R1II_{MIN} + R2II_{MIN} + RNII_{MIN})/N$, where N = the number of the last replication or the total number of replications

(2) Mean $II_{MAX} = (R1II_{MAX} + R2II_{MAX} + RNII_{MAX})/N$, where N = the number of the last replication or the total number of replications

(3) Mean ICR = Mean II_{MAX} - Mean II_{MIN}

9.9.3 Calculation of FCR. Calculation for the Final Current Range (coded FCR) shall be performed for each replication using the following formula:

$$FCR = FI_{MAX} - FI_{MIN}$$

9.9.4 Calculation of Mean FI_{MIN} , Mean FI_{MAX} , and Mean FCR. Calculation for the means of all "Final" current levels and current ranges for all replications (coded R1, R2, etc.) shall be performed using the following formulas:

(1) Mean $FI_{MIN} = (R1FI_{MIN} + R2FI_{MIN} + RNFI_{MIN})/N$, where N = the number of the last replication or the total number of replications

(2) Mean $FI_{MAX} = (R1FI_{MAX} + R2FI_{MAX} + RNFI_{MAX})/N$, where N = the number of the last replication or the total number of replications

(3) Mean FCR = Mean FI_{MAX} - Mean FI_{MIN}

9.9.5 Calculation of Mean Current Levels and Current Ranges for All Data (Initial and Final). Calculation for the means of all I_{MIN} and I_{MAX} current levels and all current ranges (Initial and Final) for all replications shall be performed using the following formulas:

(1) Mean All $I_{MIN} = (\text{Mean } II_{MIN} + \text{Mean } FI_{MIN})/2$

(2) Mean All $I_{MAX} = (\text{Mean } II_{MAX} + \text{Mean } FI_{MAX})/2$

(3) Mean All CR = Mean All I_{MAX} - Mean All I_{MIN}

9.10 Test Report

9.10.1 All of the following informational items shall be reported on the Endurance Test Report (see Annex B):

(1) Date(s) of test and the report date

- (2) Name and address of testing facility
- (3) Name of test operator and signature
- (4) List and description of all test equipment
- (5) Any variances to specified test equipment
- (6) All welding parameters (including electrodes)
- (7) Any variances to the test procedure
- (8) The test code for the test(s) (assigned by the operator or the party for whom the test is being conducted)

9.10.2 All of the following welding data shall be reported on the Endurance Test Report (see Annex B):

(1) Initial currents (II_{MIN} and II_{MAX}) and current range (ICR) for each replication

(2) Final currents (FI_{MIN} and FI_{MAX}) and current range (FCR) for each replication

(3) Initial and Final I_{MIN} and I_{MAX} weld-button sizes (ID_{MIN} , ID_{MAX} , FD_{MIN} , and FD_{MAX}) for each replication

(4) Mean Initial currents (Mean II_{MIN} and Mean II_{MAX}) and current range (Mean ICR) for all replications

(5) Mean Final currents (Mean FI_{MIN} and Mean FI_{MAX}) and current range (Mean FCR) for all replications

(6) Mean of all currents (Mean All I_{MIN} and Mean All I_{MAX}) and current ranges (Mean All CR) for all replications

(7) Electrode endurance (no. of welds) to the specified termination point or an optional end point (decided by the party for whom the test is performed)

9.10.3 Data for the electrode-face diameters shall be reported on the Endurance Test Report (see Annex B). The mean electrode-face diameters [directly measured or the adjusted means (tip-imprint correction factor) from tip imprints] of both electrodes (top and bottom) and their composite (except for number one below) shall be reported for the following points in the test (other points optional):

(1) In the as received or as-machined condition before installation (measured directly, not from tip imprints)

(2) After the final electrode dressing

(3) After completion of the electrode-face stabilization procedure

(4) After the Initial I_{MAX} has been determined

(5) After the Endurance Limit has been reached

(6) After the Final I_{MAX} has been determined

10. Weld Property Tests

10.1 Introduction and Overview. The Weld Property Test Procedure is designed to assess spot welding behavior and weld properties of uncoated and coated sheet steel using several criteria. These criteria include I_{MIN} and I_{MAX} currents and current range, hold-time sensitivity tests, shear tension and cross tension tests, and metallographic/hardness tests. This test procedure may be

performed independent of or in conjunction with the Endurance Test Procedure.

10.2 Test Preparation

10.2.1 Before proceeding, an adequate quantity of test coupons and panels of the various types required in these tests shall be prepared using the instructions in section 3, Sample Preparation. If required or desired, material characterization may be performed per section 4, Material Characteristics, if this has not been done.

10.2.2 The appropriate welding parameters and electrodes shall be determined for the material being tested by consulting Table 3. A new set of electrodes shall be installed per section 7, Electrode Installation and Dressing Procedure, and the electrode-face/weld size stabilization shall be performed per section 8, Electrode-Face and Weld-Size Stabilization, using the selected parameters.

10.2.3 After the stabilization procedure has been completed, it shall be ascertained that all welding parameters are still at their specified values and that the hold time is set to the short hold time (see Table 3). All required information shall be entered on the Welding Data Sheet (if this has not yet been done) according to 8.2.2. The items in 8.2.3 shall be checked, and all required data shall be recorded per 8.2.4 as welds are made and tested. Figure 9 shows the surface orientation of peel-test samples (coated sheet steel only) that shall be kept constant for all tests.

10.2.4 The minimum weld-button size (MWS) shall be calculated for the sheet thickness being tested using the formula found in 5.7.1.

10.3 I_{MIN} Current Determination. All welds are at the short hold time.

10.3.1 Based on weld size and welding current data from the weld stabilization procedure (Section 8), the current setting shall be adjusted low enough to produce a weld that is at least 0.5 mm smaller than the MWS (ideally 0.5 to 1.0 mm smaller than the MWS). One peel-test sample shall be welded and tested at this current. If the resulting weld button is:

- (1) smaller than MWSW—0.5 mm, step 10.3.2 follows.
- (2) larger than MWS—0.5 mm (e.g., larger than 3.1 mm for an MWS of 3.6), the current shall be reduced in increments of 300 A, and one peel-test sample shall be welded and tested at each increment until the weld-button size is smaller than MWS – 0.5 mm. When this condition has been met, step 10.3.2 follows.

10.3.2 The current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample (any orientation type) shall be welded and tested until a weld button is obtained that satisfies

both the MWS and the fracture-mode requirements (see 5.7.6) for I_{MIN} . *Note: After both I_{MIN} criteria have been met by a peel-test sample, a reduction in current is never allowed even though the button diameter may be greater than the minimum.* The orientation type [C, L, or R (see Figure 7)] of the first peel sample that meets both I_{MIN} criteria shall be recorded.

10.3.3 Using both of the other two sample orientation types not used in step 10.3.2 (i.e., if orientation C was used in step 10.3.2, L and R shall be used in this step), two peel-test samples shall be welded and tested at the same I_{MIN} current setting found in step 10.3.2.

10.3.3.1 If both of these samples meet the I_{MIN} criteria, step 10.3.4 follows.

10.3.3.2 If either of these samples does not satisfy the I_{MIN} criteria, the current setting shall be increased in increments of approximately 100 A, and peel-test samples shall be welded and tested until samples of all three orientations (all welded consecutively at the same current setting) meet the I_{MIN} criteria. After this criterion is met, step 10.3.4 follows.

10.3.4 I_{MIN} shall be calculated (in kA rounded to the nearest 0.1 kA) by averaging the current (recorded to 0.1 kA) measured for the test welds (second weld) from the final three peel-test samples in steps 10.3.2 and 10.3.3.1 or step 10.3.3.2. The average of the measured currents for these samples is the I_{MIN} current. This current shall be coded I_{MIN} and be recorded on the Welding Data Sheet.

10.3.5 The average weld-button size shall be calculated (rounded to the closest 0.1 mm) for the three peel samples mentioned in 10.3.4. This mean weld size is the I_{MIN} button diameter. The mean shall be coded D_{MIN} and be recorded on the Welding Data Sheet.

10.4 I_{MAX} Current Determination. All welds are at the short hold time.

10.4.1 Starting from the I_{MIN} current established in Section 10.3, the current setting shall be increased in increments of approximately 100 A. At each increment, one peel-test sample shall be welded and tested until either of the two I_{MAX} criteria [expulsion (interfacial) or severe electrode-to-sheet sticking for both welds of the peel sample] is met. *Note: At each increment, the peel sample orientation is to be changed so that the three types of peel samples are sequentially used (e.g., "C", then "L", then "R", then "C", etc.).* The orientation type [C, L, or R (see Figure 5.5.1)] of all peel-test samples shall be recorded. Once one sample meets either of the I_{MAX} criteria, **welding shall cease immediately.**

10.4.2 The current measured for the test weld (second weld) of the last sample (the one that meets either of the

two I_{MAX} criteria) is the I_{MAX} current. This current shall be coded I_{MAX} . The weld-button diameter of this weld shall be coded D_{MAX} . Both I_{MAX} and D_{MAX} shall be recorded on the Welding Data Sheet.

10.4.3 After I_{MAX} has been determined, duplicate individual and composite carbon tip imprints of the electrode faces shall be made on the Tip-Imprint Data Sheet or some other suitable paper.

10.4.4 The total number of welds (one peel sample = two welds) made in 10.3 and 10.4 shall be recorded on the Welding Data Sheet, being certain not to count any imprint strokes or other non-weld strokes as welds when a mechanical weld counter is used. The weld counter shall then be reset to zero.

10.5 Hold-Time Sensitivity (HTS) Test. The objective of this test is to determine how sensitive a test material is to different rates of thermal quenching. This effect is accomplished by varying the hold time (time the electrodes remain in contact with the weld after the welding current is terminated). Two hold times ("short" and "long," see Table 3) are employed in this test. The hold times are programmed times at a frequency of 60 Hz and do not necessarily reflect actual contact time. All test welds are made at the I_{FDWS} current (weld size = specified, dressed electrode-face diameter listed in Table 3). Shown in Table 7 are the combinations and conditions that are used.

10.5.1 Restabilization of the Electrode Faces. Based on the I_{MIN} and I_{MAX} data from 10.3 and 10.4, the current shall be reset to a level which will produce weld sizes that are approximately 80 to 90 percent of the specified electrode-face diameter (e.g., 4 to 4.5 mm for a 5 mm electrode face) and 19 welds shall be made on an electrode conditioning panel. The objective of these welds is to restabilize the electrode faces from the expulsion,

sticking, or both that was encountered during the I_{MAX} determination.

10.5.2 Welding The HTS Panels

10.5.2.1 Determining I_{FDWS} (current required to achieve the FDWS). With the weld controller set to the "short" hold time (see Table 3) and the current set to that used in step 10.5.1, the current shall be increased in increments of 100 A, welding and testing one peel-test sample (any sample orientation) at each increment until a weld size that is 90 percent (or slightly greater) of the FDWS is achieved. Two additional peel-test samples (each a different sample orientation) shall then be welded at this current. These additional samples shall be tested, and the mean weld size for the three samples shall be calculated. If the mean weld size of these three samples does not equal or slightly exceed the FDWS, the current shall be increased in increments of 100 A, and three peel-test samples shall be welded and tested at each increment until the FDWS is reached or slightly exceeded by the mean of three peel samples (each welded in a different sample orientation and all three welded consecutively at the same current setting).

Note: If expulsion is encountered on any weld, before achieving the FDWS, welding shall cease and the current setting that is just below where expulsion was noted shall be used for I_{FDWS} . If the tolerance of ± 0.2 mm from the FDWS cannot be achieved, the current setting that produces the closest achievable tolerance that is not greater than $FDWS + 0.2$ mm and is without any expulsion welds in the three samples shall be used. The following examples cover several possible scenarios:

(1) If Mean 1 = 4.9 mm and Mean 2 (at the next higher current increment) = 5.1 mm for an FDWS of 5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting of Mean 2 shall be used. (When both means are within equal tolerance, the larger weld size is preferred.)

(2) If Mean 1 = 4.9 mm and Mean 2 (at the next higher current increment) = 5.2 mm for an FDWS of 5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting of Mean 1 shall be used. (Mean 1 is closer to the FDWS.)

(3) If Mean 1 = 4.7 mm and Mean 2 (at the next higher current increment) = 5.3 mm for an FDWS of 5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting of Mean 1 shall be used. (Mean 2 exceeds $+0.2$ mm tolerance.)

(4) If Mean 1 = 4.6 mm and Mean 2 (at the next higher current increment) = 4.8 mm for an FDWS of 5 mm but the last weld (test weld of sample 3) in the Mean 2 group exhibited expulsion, the current setting of Mean 1 shall be used.

Table 7
Conditions/Combinations for
Hold-Time Sensitivity (HTS) Tests

Panel No.	Weld Size	Current	Hold Time*	Panel Use
1	FDWS	I_{FDWS}	Short	Peeling
2	FDWS	I_{FDWS}	Short	Met./Hardness
3	FDWS	I_{FDWS}	Long	Peeling
4	FDWS	I_{FDWS}	Long	Met./Hardness

*See Table 3.

10.5.2.2 Welding HTS Panels 1 and 2 (Short Hold Time). Once the I_{FDWS} current setting is determined (per 10.5.2.1), HTS Panel 1 shall be welded as shown in Figure 19 using the designated weld sequence and weld spacing. The welding current of each weld on Panel 1 shall be recorded. The panel and each weld shall be properly coded. The mean welding current for the seven welds in Panel 1 shall be calculated, and it shall be determined whether condition (1) or condition (2) noted below applies.

(1) If the mean welding current of the Panel 1 welds is within ± 100 A of the I_{FDWS} current determined in 10.5.2.1, Panel 2 shall be welded at this same current setting. The welding current of each weld on Panel 2 shall be recorded. Each weld and panel shall be properly coded. Step 10.5.2.4 follows.

(2) If the mean of the measured welding currents for Panel 1 welds is more than 100 A below the I_{FDWS} current from 10.5.2.1 (because of inductive mass and impedance effects of the panel on the current produced by constant voltage welding machines), Panel 1 shall be discarded and the instructions in step 10.5.2.3 shall be followed.

10.5.2.3 The current setting shall be increased one increment (1 percent or 100 A) at a time, and one HTS panel shall be welded at each increment until the mean

welding current equals or exceeds (by no more than 100A) the I_{FDWS} current determined in 10.5.2.1. The panel that produces the mean welding current closest to the I_{FDWS} current without exceeding it by more than 100 A becomes the new Panel 1. Panel 2 shall be welded at this same current setting. The welding current of each weld on Panels 1 and 2 shall be recorded. Each panel and weld shall be properly coded. *Note: All HTS panels other than Panels 1 and 2 just completed shall be discarded.*

10.5.2.4 Welding HTS Panels 3 and 4 at the Long Hold Time. Without adjusting the current setting (that used for welds on HTS Panels 1 and 2 in 10.5.2.2 or 10.5.2.3), the hold time shall be increased to 90 cycles and Panels 3 and 4 shall be welded. The welding current of each weld on Panels 3 and 4 shall be recorded. Each panel and weld shall be properly coded.

10.5.3 Sectioning and Testing of HTS Panels

10.5.3.1 Sectioning. After all four HTS panels are welded, each panel shall be sectioned into individual HTS samples by shearing or saw cutting at the dotted lines in Figure 19. The width of these samples is given in Table 7. *Note: All samples are to be properly coded prior to sectioning so that panel and weld codes are not lost during the sectioning operation.*

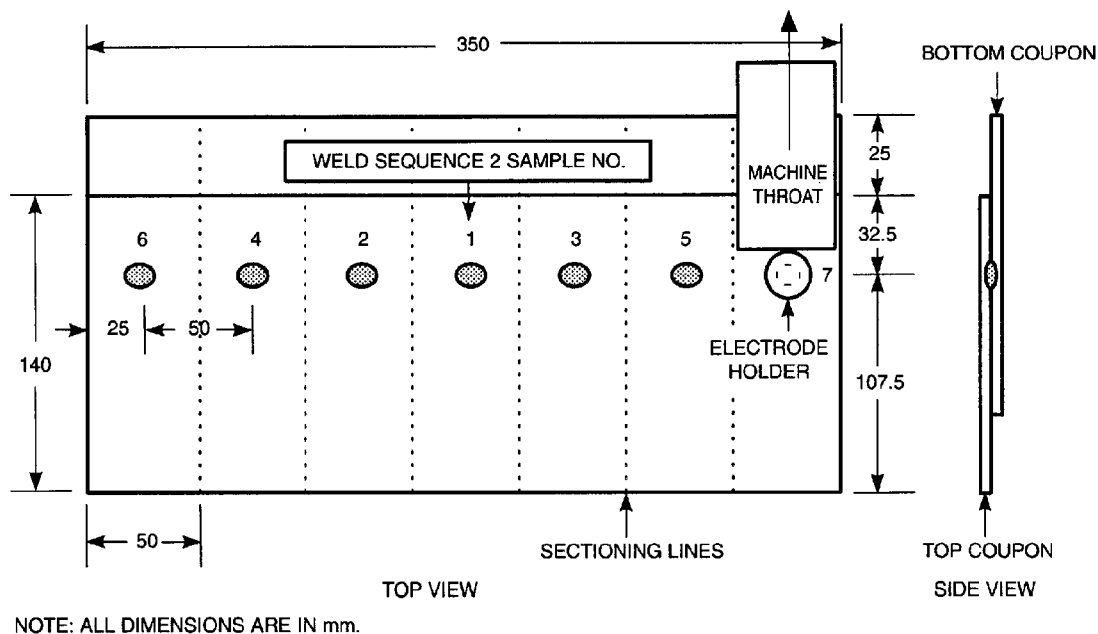


Figure 19—Weld Layout for HTS Panels

10.5.3.2 Peel Testing. All welds from Panels 1 and 3 shall be peel tested using standard peel testing techniques and equipment. The size of each weld shall be measured and recorded per standard procedure (see 5.7.4), and the weld-button fracture mode shall be determined (see Section 5.7.5) and recorded. *Note: For any partial interfacial fractures (PIF) or full interfacial fractures (FIF), the diameters of the entire fused area (button and interfacial fracture) and the weld button are to be measured. The diameter for the total fused area shall be enclosed in brackets. For example: 3.6 mm (4.9 mm) indicates that the mean diameter of the pulled out, partial button is 3.6 mm and the mean diameter of the fused area is 4.9 mm.*

10.5.3.3 Metallographic/Hardness Testing. *Note: Hardness testing shall be performed at the discretion of the party for whom the material is tested. Hardness testing is highly recommended on high-strength sheet steels, but may be applied to all materials.*

(1) Sample Preparation. Two HTS samples shall be randomly selected from each of the even-numbered panels (Panels 2 and 4). One of the samples from each panel shall be sectioned slightly offset from its weld centerline so that the centerline is parallel to the sample length [see Figure 20(A)]. These samples are defined as the longitudinal metallographic samples and are to be coded as such. The other sample from each panel shall be sectioned slightly offset from its weld centerline so that the centerline is perpendicular to the sample length [see Figure 20(B)]. These samples are defined as the transverse metallographic samples and are to be coded as such. *Note: The offset from the weld centerline has to be sufficient so that the specimens can be ground and polished to the centerline of the weld during specimen preparation.*

tion. All specimens shall be mounted and polished to the centerline for metallographic examination and micro-indentation hardness testing.

(2) Weld Microstructure. After completion of the final polish, photomicrographs (10 to 20X) shall be taken of all specimens in the unetched condition. After the desired photographs of the unetched samples are taken, the specimens shall be etched in a suitable etchant to bring out the weld features (weld nugget, heat-affected zone) and base metal. Any specified or desired (as determined by the specifying party) photomicrographs and photomicrographs shall be taken after etching and prior to hardness testing.

(3) Hardness Testing. Hardness testing shall be performed as shown in Figure 21 (diagonal traverse across the weld from base metal of top coupon to base metal of bottom coupon) using a suitable instrument for micro-indentation hardness testing (Vickers or Knoop). All hardness testing shall be performed at a temperature of $23 \pm 5^\circ\text{C}$. A constant force that is between 0.2 kg (1.961 N) and 1 kg (9.807 N) shall be used for all indentations. All indentations shall be made at 0.4 mm spacings or no less than three times the mean diagonal of any two adjacent indentations. *Note: If the distance between the centers of two adjacent indentations is less than three times the mean diagonal of either indentation, the spacing has to be increased.* The approach velocity of the indenter shall not exceed 200 $\mu\text{m}/\text{second}$. The time from initial application of force until the test force is reached shall not exceed 10 seconds. The duration of the test force shall be 10 to 15 seconds. The results shall be reported in tabular or graphical form.

10.6 Shear and Cross Tension Tests. The objective of these tests is to determine the shear tension and direct (cross) tension strengths of a test material at two hold

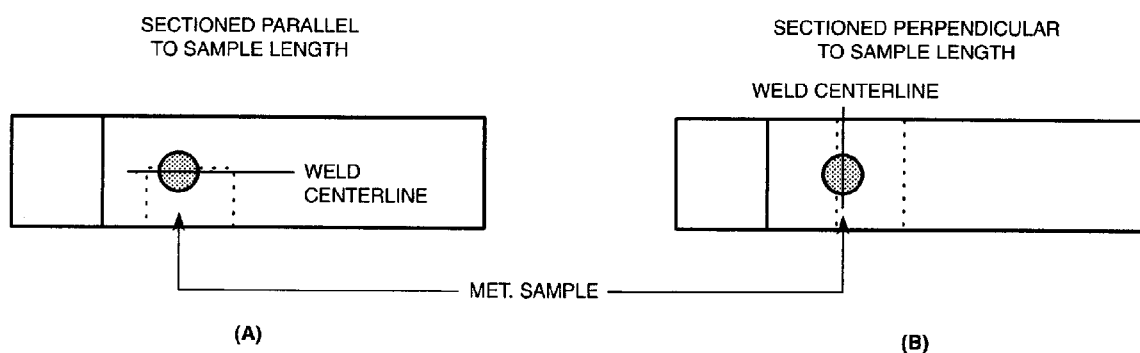


Figure 20—Sectioning of Test Welds for Metallographic Examination and Hardness Testing

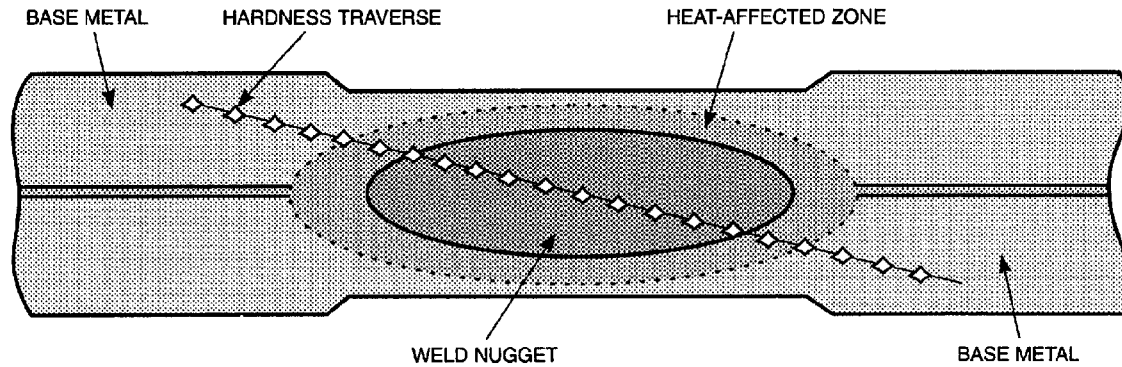


Figure 21—Cross-Sectioned Weld and Hardness Traverse

times (“short” and “long,” see Table 3). The hold times are programmed times at a frequency of 60 Hz and do not necessarily reflect actual contact time. All test welds are made at the I_{FDWS} current (weld size = specified, dressed electrode-face diameter listed in Table 3).

Note: Because all test welds on these samples are single welds, the I_{FDWS} current required to produce the proper weld size may be slightly different (probably lower) from the I_{FDWS} current that is required for the HTS tests. To distinguish between the two currents, the current required for all shear and cross tension samples will be designated I_{FDWS2} . Table 8 shows the combinations and conditions used. Table 9 and Figure 22 show the dimensions and schematic for the shear tension samples. Table 10 and Figure 23 show specimen dimensions and schematic for the cross tension samples.

10.6.1 Welding Shear and Cross Tension Samples

10.6.1.1 Determining I_{FDWS2} (current required to achieve the FDWS on shear and cross tension samples). The weld controller shall be set to the “short” hold time, and the welding current shall be reduced approxi-

mately 500 A from the I_{FDWS} current setting (see 10.5) for the HTS panel welds. Starting from this current ($I_{FDWS} - 500$ A), the current shall be increased in increments of 100 A, and one shear tension sample shall be welded (according to the specifications in Table 9 and Figure 22) and peel tested at each increment until a weld size that is 90 percent (or slightly greater) of the FDWS is achieved. Once this criterion is met, two additional shear tension samples shall be welded at this current. These samples shall be peel tested, their button diameters measured, and the mean weld size calculated for all three samples.

If the mean weld size of these three samples does not equal or slightly exceed the FDWS, the current shall be increased in increments of 100 A until the FDWS is reached or slightly exceeded by the mean of three shear tension samples (all three welded consecutively at the same current setting). This current shall be coded I_{FDWS2} . *Note: If expulsion is encountered on any weld, before achieving FDWS, welding shall cease, and the current setting that is one increment below where expulsion was noted shall be used for I_{FDWS2} .* If the tolerance of ± 0.2 mm from the FDWS cannot be achieved, the current setting that produces the closest achievable tolerance that is not greater than $FDWS + 0.2$ mm and is without any expulsion welds in the three samples shall be used. The following examples cover several possible scenarios:

(1) If Mean 1 = 4.9 mm and Mean 2 (at the next higher current increment) = 5.1 mm for an FDWS of 5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting for Mean 2 shall be used. (When both means are within equal tolerance, the larger weld size is preferred.)

(2) If Mean 1 = 4.9 mm and Mean 2 (at the next higher current increment) = 5.2 mm for an FDWS of

Table 8
Conditions/Combinations for
Shear and Cross Tension Tests

Condition No.	Weld Size	Current	Hold Time*
1	FDWS	I_{FDWS2}	Short
2	FDWS	I_{FDWS2}	Long

*See Table 3.

Table 9
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

Notes:

a. May be increased to accommodate gripping fixtures.

b. Tolerance: ± 1 mm.

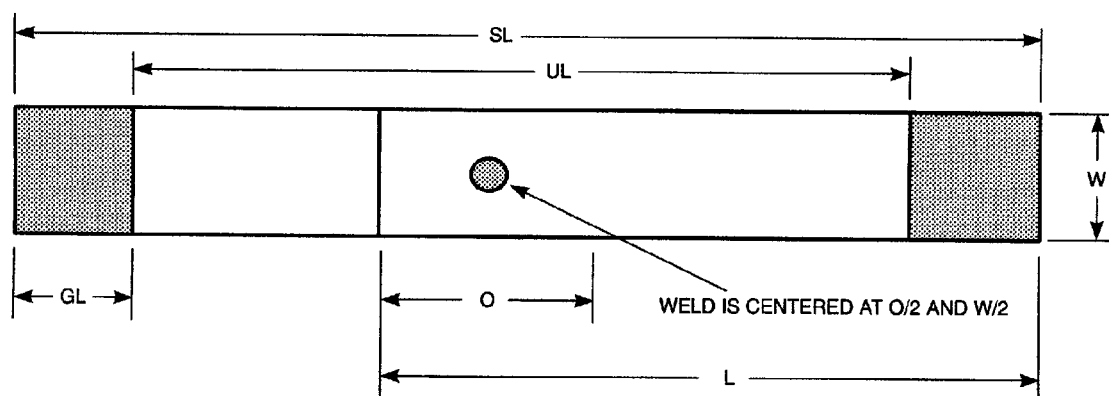


Figure 22—Schematic for Shear Tension Samples

5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting for Mean 1 shall be used. (Mean 1 is closer to the FDWS.)

(3) If Mean 1 = 4.7 mm and Mean 2 (at the next higher current increment) = 5.3 mm for an FDWS of 5 mm and none of the welds for either Mean 1 or Mean 2 exhibited expulsion, the current setting for Mean 1 shall be used. (Mean 2 exceeds +0.2 mm tolerance.)

(4) If Mean 1 = 4.6 mm and Mean 2 (at the next higher current increment) = 4.8 mm for an FDWS of 5 mm but the last weld (sample 3) in the Mean 2 group exhibited expulsion, the current setting for Mean 1 shall be used.

10.6.1.2 Welding the Shear and Cross Tension Samples at the Short Hold Time. Once the I_{FDWS2} current setting is determined (per 10.6.1.1), three shear tension samples shall be welded (according to the specifications in Table 9 and Figure 22) and three cross tension samples (according to the specifications in 10

and Figure 23). The welding current of each weld shall be recorded and each specimen is to be properly coded.

10.6.1.3 Welding the Shear and Cross Tension Samples at the Long Hold Time. Without adjusting the I_{FDWS} current used to weld the specimens in 10.6.1.2, the hold time shall be increased to 90 cycles, three shear tension samples shall be welded (according to the specifications in Table 9 and Figure 22), and three cross tension samples shall be welded (according to the specifications in Table 10 and Figure 23). The welding current of each weld shall be recorded and each specimen is to be properly coded.

10.6.3 Testing of Shear and Cross Tension Specimens. For each sample, the ultimate tensile load shall be recorded. Also, the size of each weld shall be measured and recorded per standard procedure (see 5.7.4), and the weld-button fracture mode shall be determined (see 5.7.5) and recorded. *Note: For any partial interfacial fractures (PIF) or full interfacial fractures (FIF), the diameters of the entire fused area (button and interfacial*

Table 10
Cross Tension Sample Dimensions

Sheet Thickness (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

Notes:

a. Tolerance: +0, -0.5 mm.

b. Tolerance: +0, -1.0 mm.

c. Tolerance: ± 0.2 mm.

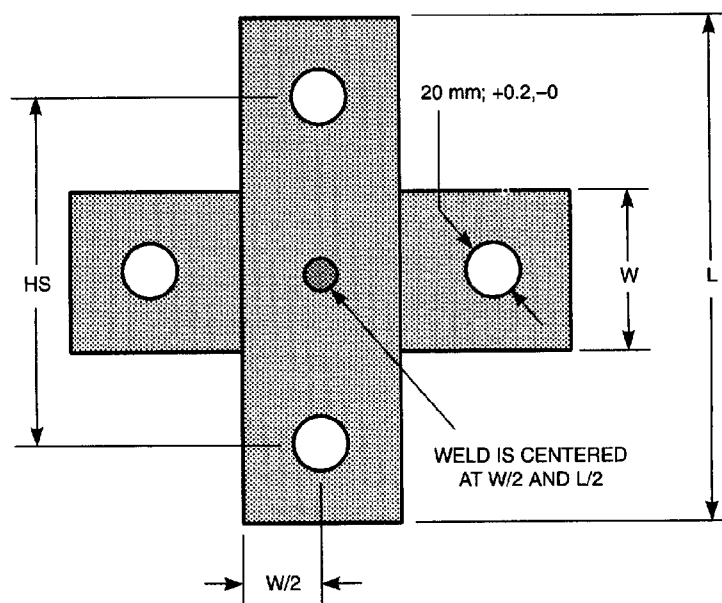


Figure 23—Schematic for Cross-Tension Samples

fracture) and the weld button are to be measured. The diameter for the total fused area shall be enclosed in brackets. For example: 3.6 mm (4.9 mm) indicates that the mean diameter of the pulled out, partial button is 3.6 mm and the mean diameter of the fused area is 4.9 mm.

10.6.3.1 Shear Tension Samples. All testing shall be performed at room temperature ($20 \pm 5^\circ\text{C}$) on a suitable, calibrated tensile testing machine. A cross head velocity of 10 mm/minute shall be used for all tests. The specimens shall be gripped so that the ungripped (UL) and gripped (GL) lengths are as listed in 9. Shims of the same thickness as the test material shall be used on all specimens as shown in Figure 24.

10.6.3.2 Cross Tension Samples. All testing shall be performed at room temperature ($20 \pm 5^\circ\text{C}$) on a suitable, calibrated tensile testing machine. A cross head velocity of 10 mm/minute shall be used for all tests. The specimens shall be gripped in a suitable fixture so that bending of the specimen is minimized. A typical gripping fixture (two required) is shown in Figure 25.

10.7 Replication. Any individual or all portions of the Weld Property Test may be replicated as many times as deemed necessary by the party specifying the test.

10.8 Test Report. All of the following items shall be reported on the Weld Property Test Report sheet:

(1) General Items

(a) Date(s) of test and the report date

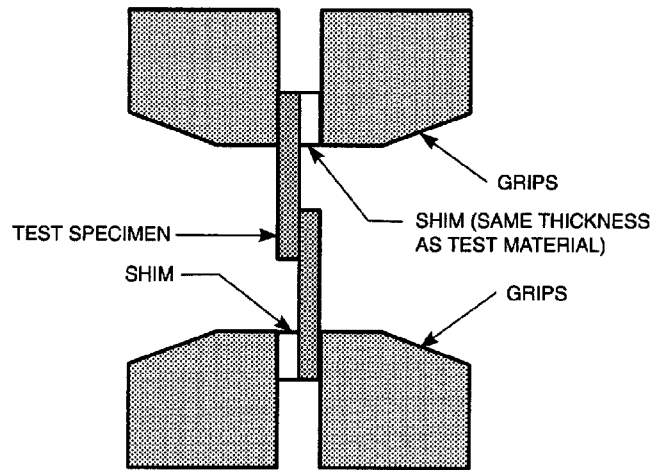


Figure 24—Schematic for Testing of Shear-Tension Samples

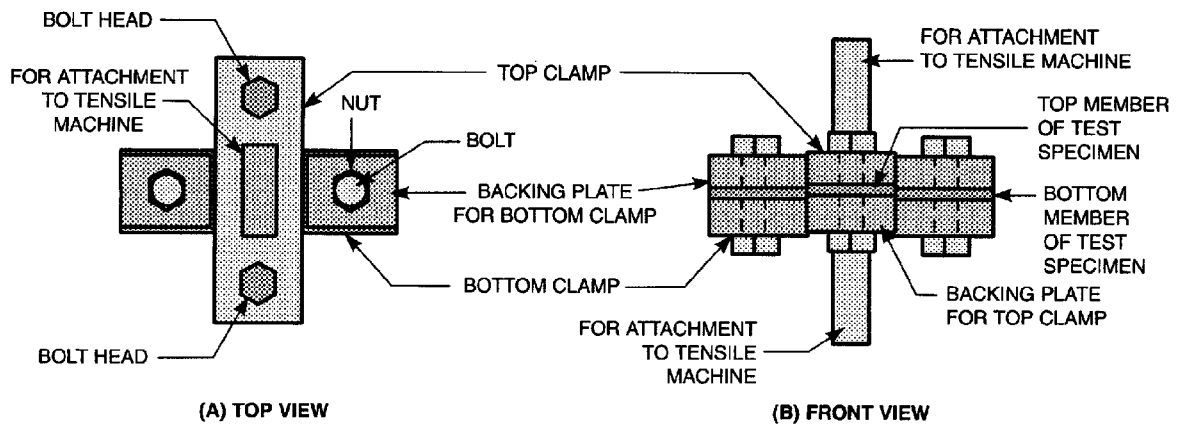


Figure 25—Test Fixture Schematic for Testing of Cross-Tension Samples

- (b) Name and address of testing facility
- (c) Name of test operator and signature of person approving the test report
- (d) List and description of all test equipment
- (e) Any variances to specified test equipment
- (f) All welding parameters (including electrodes)
- (2) Current Level and Current Range Data for Each Replication
 - (a) I_{MIN}
 - (b) I_{MAX}
 - (c) Current range ($I_{MAX} - I_{MIN}$)
- (4) Hold-Time Sensitivity Data
 - (a) Mean I_{FDWS} welding currents for each hold time
 - (b) Mean button and fused area diameters for each hold time

- (c) Number of PIF and FIF welds at each hold time
- (d) Plot or tabular list of hardness traverse (optional)
- (5) Shear Tension Data
 - (a) Mean I_{FDWS} welding currents for each hold time
 - (b) Mean button and fused area diameters for each hold time
 - (c) Number of PIF and FIF welds at each hold time
 - (d) Mean shear tension strength at each hold time
- (6) Cross Tension Data
 - (a) Mean I_{FDWS2} welding currents for each hold time
 - (b) Mean button and fused area diameters for each hold time
 - (c) Number of PIF and FIF welds at each hold time
 - (d) Mean cross tension strength at each hold time

Annex A

Electrodes

(This Annex is not a part of ANSI/AWS D8.9-97, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*, but is included for informational purposes only.)

Annex A describes the electrode type and dimensions that shall be used for most material qualification testing of sheet steel materials. However, if required by special circumstances, other electrode types may be used with the consent of the party for whom the testing is performed. If electrodes other than those listed in Table A1 are used, special note of this deviance is to be made on the welding data sheets and all test reports.

A1. Electrode Geometry

Male, truncated cone electrode caps having the dimensions listed in Table A1 and Figure A1, and having

the properties in A2 shall be used for all testing except where special circumstances apply.

A2. Electrode Composition and Properties

The electrodes shall be produced to RWMA Group A, Class 2 CuCr (RWMA 2.18200) specifications with a 75 Rb minimum hardness.

Table A1
Electrode Specifications and Dimensions

	Electrode Type (mm)	1	2	3	4	5	6	Tol.
A	Dressed Face Diameter	4.5	5.0	6.0	7.0	8.0	9.0	±0.1
	Face Diameter	4.4	4.9	5.9	6.9	7.9	8.9	±0.1
B	Body Diameter	15.9	15.9	15.9	19.0	19.0	22.0	±0.1
C	Length	29.0	29.0	29.0	32.0	32.0	32.0	±0.2
D	Shank Length	12.7	12.7	12.7	15.9	15.9	15.9	±0.2
E	Face Thickness	9.7	9.7	9.7	9.7	9.7	9.7	±0.5
F	Hole Diameter	8.1	8.1	8.1	9.7	9.7	12.7	±0.3
G	Taper Loc. per Ford Spec.	9.9	9.9	9.9	13.4	13.4	13.4	±0.1
	per RWMA Spec.	9.9	9.9	9.9	12.7	12.7	12.7	±0.1
H	Taper Dia. per Ford Spec.	10.54	10.54	10.54	14.33	14.33	17.81	±0.01
	per RWMA Spec.	10.54	10.54	10.54	12.725	12.725	15.57	±0.01
T	Taper Angle*	1.43°	1.43°	1.43°	1.43°	1.43°	1.43°	±0.05°
Angle	Bevel Angle	45°	45°	45°	45°	45°	45°	±1°

*1.43° = Resistance Welding Manufacturers Association (RWMA) Taper No 5. 1.43° (1°26') is equivalent to a diameter reduction ratio of 1/20, i.e., H - G/20 = diameter at shank end (without edge chamfering). Other tapers (RWMA #6 or others) are also permissible if required to fit your electrode adapters.

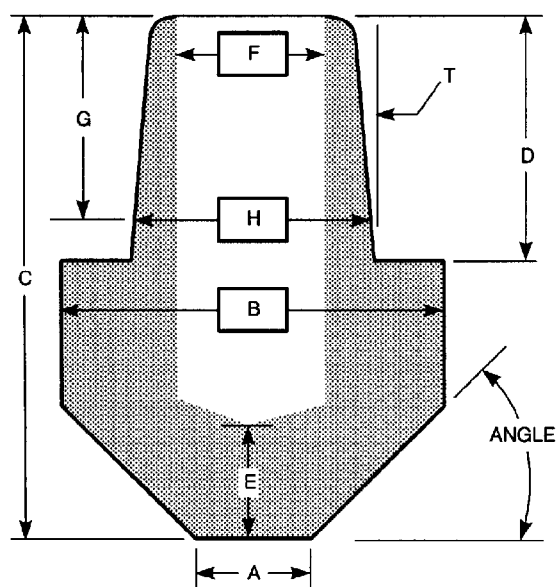


Figure A1—Spot Welding Electrode Diagram

Annex B

Data Forms

(This Annex is not a part of ANSI/AWS D8.9-97, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*, but is included for informational purposes only.)

Found in this Annex are standard forms for recording welding data, tip imprints, material data, and test results. It is strongly recommended that copies of these forms (available from AWS) be used whenever conducting the test methods of this document. However, variations of these forms to suit the user's needs are permissible. The following sections provide a brief description of each form.

B1. Welding Data Sheet (Form B-1)

This form is used for recording all welding test data and welding parameters listed on the forms. Page 1 (front page) of Form B-1 is shown on page 42, and a continuation page is shown on page 43. The continuation pages are designed for recording of additional data in a test and thus do not contain the equipment, parameter, and other information found on the cover page. The test code, date, and page numbers shall be entered on all continuation pages required per test. Besides welding parameters and test data, the following shall be recorded on Page 1:

- (1) Laboratory name and address, test code and type, and test operator and date
- (2) Sheet steel type and thickness; coating type and nominal coating weight; and coil, heat, or other identification (ID) number
- (3) Welding machine ID, control type, and tap setting; electrode ID, nominal face diameter, and face thickness; and cooling tube diameter
- (4) Current analyzer type and ID; force gage type and ID; welding mode (manual or robotic); and panel type (standard or optional)

B2. Tip-Imprint Data Sheet (Form B-2)

This form is used for recording the as-machined, measured electrode-face diameters before dressing and all

tip-imprint measurements listed on the form. Page 1 of Form B-2 and a continuation page are shown on pages 44 and 45, respectively. If possible, these forms should also be used for taking the tip imprints in the boxes provided.

B3. Test Material Data Sheet (Form B-3)

This form is used for recording the test material's properties and other data. Page 1 of Form B-3 is shown on page 46 and lists the mandatory data. Page 2 (shown on page 47) is for optional mechanical property and surface roughness data.

B4. Endurance Test Report (Form B-4)

Form B-4 is used to report information and data from the Endurance Test. Page 1 (shown on page 48) is used for reporting all test material data, test equipment information, and welding parameters. Test results from the Endurance Test are reported on Page 2 (shown on page 49).

B5. Weld Property Test Report (Form B-5)

Form B-5 is used to report information and data from the Weld Property Test. All test material data, test equipment information, and welding parameters are reported on Page 1 (shown on page 50). Test results from the Weld Property Test are reported on Pages 2 and 3 (shown on pages 51 and 52).

[illegible]

Form B-1 (Continued)

Tip Imprint Data Sheet

Laboratory Name _____

Address _____

Test Code _____ Test Type _____ Test Date _____

Test Operator _____

Comments _____

Electrode-Face Diameters of Undressed (As-Machined) Electrodes			Top Electrode (mm)			Bottom Electrode (mm)		
			Minimum	Maximum	Mean (T)	Minimum	Maximum	Mean (B)

Carbon Paper Tip Prints			Code	Print Measurements								
				Top Electrode (mm)			Bottom Electrode (mm)			Composite (mm)		
Composite	Top Electrode	Bottom Electrode		Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
			UD-1			TUD-1			BUD-1			
			UD-2			TUD-2			BUD-2			
Example: $TU = (TUD-1 + TUD-2)/2$				TU =			BU =					
Example: $TCF = TU - T$				TCF =			BCF =					
CF = $(TCF + BCF)/2$				CF =								
			AD1-1			TAD1-1			BAD1-1			
			AD1-2			TAD1-2			BAD1-2			
Example: $TD1 = (TAD1-1 + TAD1-2)/2$				TD1 =			BD1 =					
Example: $TCD1 = TD1 - CF$				TCD1 =			BCD1 =					
			AD2-1			TAD2-1			BAD2-1			
			AD2-2			TAD2-2			BAD2-2			
Example: $TD2 = (TAD2-1 + TAD2-2)/2$				TD2 =			BD2 =					
Example: $TCD2 = TD2 - CF$				TCD2 =			BCD2 =					

Form B-2

Date _____

[illegible]

Test Material Data Sheet

Laboratory Name _____

Address _____

Coil No. or ID _____ Reporter Name _____ Report Date _____

Steel Grade _____ Coating Type _____ Nominal Coating Wt. _____ g/m² _____ g/m²

Surface Lubricants _____ Brand Name _____ Type _____ Post-Coating Treatment _____ Brand Name _____ Type _____

Comments _____

Mandatory Material Data**Sheet Thickness**

Trimmed Edge X (mm)	1/4 Point (mm)	Center Point (mm)	3/4 Point (mm)	Trimmed Edge Y (mm)	Mean (mm)	Std. Dev. (mm)

Sheet Coating Weight

Side (Top* or Bottom)	Trimmed Edge X (g/m ²)	Center Point (g/m ²)	Trimmed Edge Y (g/m ²)	Mean (mm)	Std. Dev. (mm)	Test Method Used

*Note: Top side is marked side.

Sheet Coating Composition (% Weight)

Sample Number	Sample 1						Sample 2					
Element												
Top* Side												
Bottom Side												

*Note: Top side is marked side.

Sheet Substrate Composition (% Weight)

Element												
Analysis												

Form B-3

Optional Material Data

Mechanical Properties							
Category	Yield (MPa)	UTS (MPa)	Elong. (%)	R	N	Test Method Used	Comments
Sample 1							
Sample 2							
Sample 3							
Mean							

Sheet Surface Roughness												
	Ra						Peak Count					
Reading No.	1	2	3	4	5	Mean	1	2	3	4	5	Mean
Top* Side												
Bottom Side												

*Note: Top side is marked side.

Form B-3 (Continued)

Endurance Test Report

For Test Code _____

Laboratory Name _____

Report Date _____

Address _____

Reported By _____

Telephone No. _____

Approved By _____

Fax No. _____

Title _____

Material Data

Coil No. or ID _____ Steel Grade _____ Mean Thickness _____ mm

Coating Type _____ Mean Coating Wt. _____ g/m² _____ g/m²
Top Bottom

Surface Lubricants _____ Brand Name Type _____ Post-Coating Treatment _____ Brand Name Type

Other Data or Comments _____

Equipment Information

Welding Machine Type _____ Model Number _____ Machine Capacity _____ kVA

Welding Machine Tap _____ Weld Controller Name _____ Controller Mode _____

Air Cylinder Size _____ Air Cylinder Type _____ Head Velocity _____ mm/sec

Current Analyzer Brand & Model No. _____ Force Gage Brand & Model No. _____

Electrode Type (No.) _____ Dressed Face Dia. _____ mm Face Thick _____ mm _____ mm
Top Elect. Bot. Elect.

Cooling Tube-OD Dia. _____ mm Flow Meter Brand _____ Flow Meter Model No. _____

Comments or Variances to Specified Equipment _____

Welding Parameters

Weld Force _____ kN Welding Mode _____ Welding Rate _____ welds/min

Set Squeeze Time _____ cy Weld Time _____ cy Set Hold Time _____ cy Actual Hold Time _____ cy

Off Time (Repeat Welding) _____ cy Water Flow _____ l/min Water Temp _____ °C Panel Type _____

Comments or Variances to Specified Parameters _____

Endurance Test Report

For Test Code _____

Endurance Limit and Operating Current

Endurance Limit	I_{OP}
Test 1 _____ welds	_____ kA
Test 2 _____ welds	_____ kA
Test 3* _____ welds	_____ kA
Mean _____ welds	

Current Levels, Current Ranges and Weld-Button Sizes

Test 1 I_{MAX} _____ kA	ID_{MAX} _____ mm	Test 1 FI_{MAX} _____ kA	FD_{MAX} _____ mm
-Test 1 I_{MIN} _____ kA	ID_{MIN} _____ mm	-Test 1 FI_{MIN} _____ kA	FD_{MIN} _____ mm
=Test 1 ICR _____ kA		=Test 1 FCR _____ kA	
Test 2 I_{MAX} _____ kA	ID_{MAX} _____ mm	Test 2 FI_{MAX} _____ kA	FD_{MAX} _____ mm
-Test 2 I_{MIN} _____ kA	ID_{MIN} _____ mm	-Test 2 FI_{MIN} _____ kA	FD_{MIN} _____ mm
=Test 2 ICR _____ kA		=Test 2 FCR _____ kA	
Test 3* I_{MAX} _____ kA	ID_{MAX} _____ mm	Test 3* FI_{MAX} _____ kA	FD_{MAX} _____ mm
-Test 3* I_{MIN} _____ kA	ID_{MIN} _____ mm	-Test 3* FI_{MIN} _____ kA	FD_{MIN} _____ mm
=Test 3* ICR _____ kA		=Test 3* FCR _____ kA	
Mean I_{MAX} _____ kA		Mean FI_{MAX} _____ kA	
-Mean I_{MIN} _____ kA		-Mean FI_{MIN} _____ kA	
=Mean ICR _____ kA		=Mean FCR _____ kA	
Mean All I_{MAX} _____ kA			
-Mean All I_{MIN} _____ kA			
=Mean ICR _____ kA			

Mean Electrode-Face Diameters (in mm)

When Measured	Replication 1			Replication 2			Replication 3		
	Top	Bot.	Comp.	Top	Bot.	Comp.	Top	Bot.	Comp.
As Machined			—			—			—
After Final Dressing									
After Stabilization									
After Initial I_{max}									
At 1000 Welds*									
At 2000 Welds*									
At 3000 Welds*									
At 4000 Welds*									
At 5000 Welds*									
At 6000 Welds*									
At 7000 Welds*									
At 8000 Welds*									
At Endurance Limit									
After Last Weld									

Note: * = Optional wherever asterisk is shown on this page.

Form B-4 (Continued)

Weld Property Report

For Test Code _____

Laboratory Name _____

Report Date _____

Address _____

Reported By _____

Telephone No. _____

Approved By _____

Fax No. _____

Title _____

Material Data

Coil No. or ID _____ Steel Grade _____ Mean Thickness _____ mm

Coating Type _____ Mean Coating Wt. _____ g/m² _____ g/m²
Top Bottom

Surface Lubricants _____ Brand Name Type _____ Post-Coating Treatment _____ Brand Name Type

Other Data or Comments _____

Equipment Information

Welding Machine Type _____ Model Number _____ Machine Capacity _____ kVA

Welding Machine Tap _____ Weld Controller Name _____ Controller Mode _____

Air Cylinder Size _____ Air Cylinder Type _____ Head Velocity _____ mm/sec

Current Analyzer Brand & Model No. _____ Force Gage Brand & Model No. _____

Electrode Type (No.) _____ Dressed Face Dia. _____ mm Face Thick _____ mm _____ mm
Top Elect. Bot. Elect.

Cooling Tube-OD Dia. _____ mm Flow Meter Brand _____ Flow Meter Model No. _____

Comments or Variances to Specified Equipment _____

Welding Parameters

Weld Force _____ kN Welding Mode _____ Welding Rate _____ welds/min

Set Squeeze Time _____ cy Weld Time _____ cy Set Hold Time _____ cy Actual Hold Time _____ cy

Off Time (Repeat Welding) _____ cy Water Flow _____ l/min Water Temp _____ °C Panel Type _____

Comments or Variances to Specified Parameters _____

Weld Property Test Data

For Test Code _____

Current Levels, Current Ranges and Weld-Button Sizes

Test 1 I_{MAX} _____ kA	D_{MAX} _____ mm	Test 2* I_{MAX} _____ kA	D_{MAX}^* _____ mm
-Test 1 I_{MIN} _____ kA	D_{MIN} _____ mm	-Test 2* I_{MIN} _____ kA	D_{MIN}^* _____ mm
=Test 1 CR _____ kA	_____	=Test 2 CR _____ kA	
Test 3* I_{MAX} _____ kA	D_{MAX}^* _____ mm	Mean All I_{MAX} _____ kA	
-Test 3* I_{MIN} _____ kA	D_{MIN}^* _____ mm	-Mean All I_{MIN} _____ kA	
=Test 3* CR _____ kA	_____	=Mean All CR _____ kA	

Note: * = Optional Tests

Hold-Time Sensitivity Data

Hold Time	Mean I_{FDWS} Current (kA)	Mean Button and (Fused) Diameters (mm)
-----------	------------------------------	--

Setup Samples	_____	_____
Short (_____ cy)	_____	_____
Long (_____ cy)	_____	_____

Hold Time	Number of PIF + FIF Welds/Total	Hardness—See Attached Table or Figure
-----------	---------------------------------	---------------------------------------

Setup Samples	_____/_____	
Short (_____ cy)	_____/_____	
Long (_____ cy)	_____/_____	

Comments _____

Shear Tension Data

Hold Time	Mean I_{FDWS} Current (kA)	Mean Button and (Fused) Diameters (mm)
-----------	------------------------------	--

Setup Samples	_____	_____ (_____)
Short (_____ cy)	_____	_____ (_____)
Long (_____ cy)	_____	_____ (_____)

Hold Time	Number of PIF + FIF Welds/Total	Mean Shear Tension Strength (kN)
-----------	---------------------------------	----------------------------------

Setup Samples	_____/_____	_____
Short (_____ cy)	_____/_____	_____
Long (_____ cy)	_____/_____	_____

Comments _____

Form B-5 (Continued)

Weld Property Test Data

For Test Code _____

Cross Tension Data

Hold Time	Mean I_{FDWS} Current (kA)	Mean Button and (Fused) Diameters (mm)
Setup Samples	_____	_____ (_____)
Short (_____ cy)	_____	_____ (_____)
Long (_____ cy)	_____	_____ (_____)

Hold Time	Number of PIF + FIF Welds/Total	Mean Cross Tension Strength (kN)
Setup Samples	_____/_____	_____
Short (_____ cy)	_____/_____	_____
Long (_____ cy)	_____/_____	_____

Comments _____

Form B-5 (Continued)

Annex C

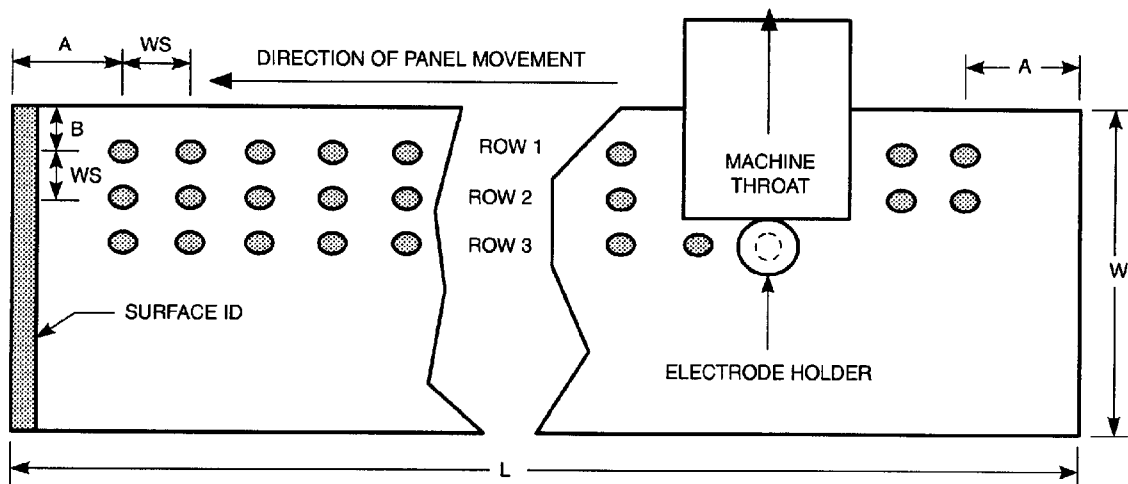
Optional Endurance Test Panel

(This Annex is not a part of ANSI/AWS D8.9-97, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*, but is included for informational purposes only.)

When material quantity is limited, the optional panel described in this Annex may be used. This Annex provides the coupon dimension of the optional panel, lists the spacings required, provides data for calculating the amount of material required, and contains instruction for using this panel for the endurance test. The panel type that is used in the test shall be recorded on the Welding Data Sheet, using code "O" for the optional panel type and "S" for the standard type.

C1. Panel Preparation. Coupon preparation, shearing, and marking of the optional panels shall be performed according to the standard instructions in section 3, Sample Preparation.

C2. Panel Welding. Panel welding for the Endurance Test shall be conducted as in 9.5 but with these additional instructions for the optional test panel. Using a sufficient number of panels (so that the panels are cool when the next row of a panel is welded), one row of welds per panel is to be made on all panels of a set of panels until the 190 welds of a checkpoint are reached. Rows 1, 2, and 3 are welded in the sequence shown in Figure C1, using the prescribed spacings listed in Table C1. After completing Rows 1, 2, and 3, the panel are rotated 180 degrees so that the same surface orientation is maintained as for the first three rows. Rows 4, 5, and 6 are welded as shown in Figure C2. *Note: The instructions for panel row sequencing and surface orientation combinations (see 5.5.3 and 5.6.2) also apply for the optional panel.*



**Figure C1—Panel Row Sequencing, Weld Spacing, and Edge Distances
for Rows 1 through 3 on the Optional Panel**

Table C1
Coupon Dimensions, Weld Spacing, and Edge Distances for Optional Panels

Sheet Thickness (mm)	L ^a (mm)	W ^{b,c} (mm)	WS ^c (mm)	A & B ^c (mm)	Area 3 ^d (m ² /weld) ^e
0.60–0.69	290	108	14	19	0.000672
0.70–0.89	310	115	15	20	0.000745
0.90–1.29	370	136	18	23	0.001079
1.30–1.69	430	157	21	26	0.001476
1.70–2.09	490	178	24	29	0.001804
2.10–3.00	550	199	27	32	0.002175

Notes:

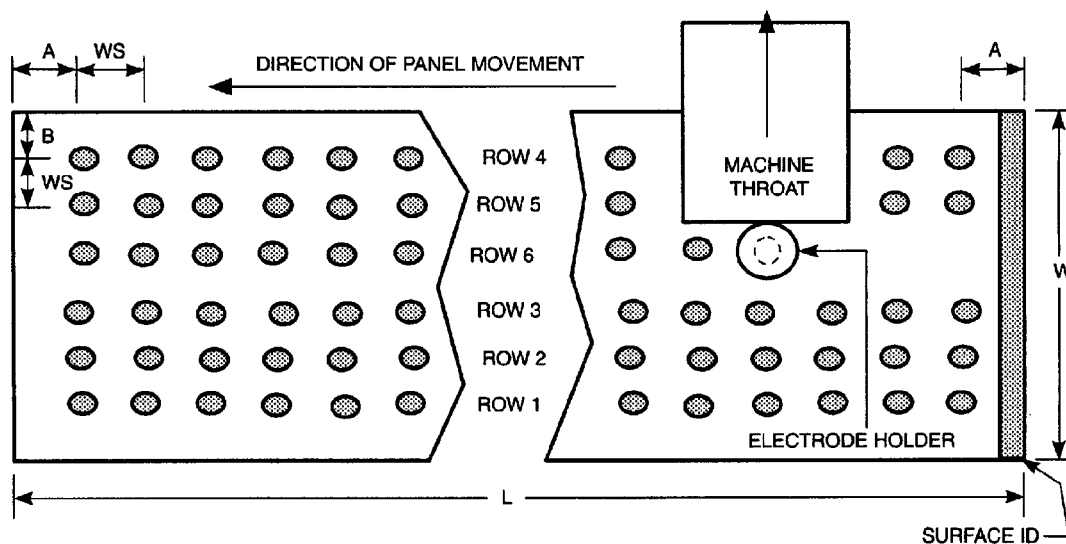
a. $L = (18 \times WS) + 2A$; Tolerance: ± 3 mm.

b. $W = (5 \times WS) + 2B$.

c. Tolerance: ± 3 mm.

d. For calculating required material quantities (see Section 3.2).

e. $1 \text{ m}^2 = 10.764 \text{ ft}^2$.



**Figure C2—Panel Row Sequencing, Weld Spacing, and Edge Distances
for Rows 4 through 6 on the Optional Panel**

Document List on Automotive Welding

AWS Designation	Title
D8.5	Recommended Practices for Automotive Portable Gun Resistance Spot Welding
D8.6	Standard for Automotive Resistance Spot Welding Electrodes
D8.7	Recommended Practices for Automotive Weld Quality—Resistance Spot Welding
D8.8	Specification for Automotive Frame Weld Quality—Arc Welding
D8.9	Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. Phone 1-800-334-9353.