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An American National Standard

Recommended Practices for Automotive Weld Quality—Resistance Spot Welding

American Welding Society

Key Words—Resistance spot welding, weld quality, destructive test, nondestructive test

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Recommended Practices for Automotive Weld Quality—Resistance Spot Welding

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Prepared by
AWS D8 Committee on Automotive Welding

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This document presents recommended practices and criteria for evaluating resistance spot welds typical of automotive sheet steel applications. The document contains weld characteristics, metrics and testing methods useful in evaluating spot welding quality on coated and uncoated automotive sheet steels of all strength levels and compositions. The test methods described are designed to assess both static and dynamic properties of automotive sheet steel welds.

American Welding Society
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Foreword

(This Foreword is not a part of AWS D8.7M:2005, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, but is included for informational purposes only.)

This document has been prepared as an informative reference to recognize a consensus of practices that may assist automotive industry suppliers in their understanding of resistance spot weld criterion and the methods for assessment of weld quality. As a recommended practice the criteria and techniques contained are not obligatory until cited as a normative reference in a mandatory document.

This recommended practice was prepared by the AWS D8D Subcommittee on Automotive Resistance Spot Welding of the AWS D8 Committee on Automotive Welding. This publication is issued under the auspices of the AWS D8 Committee on Automotive Welding.

The present publication of *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding* is an update of the original document published in 1978. This edition presents an extension of previous information along with an introduction of new data and test methodologies. These enhancements are based on research activities sponsored by resistance welding equipment manufacturers, steel companies, automotive manufacturers, universities and the United States Department of Commerce.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D8 Committee on Automotive Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Recommended Practices for Automotive Weld Quality—Resistance Spot Welding

1. Scope

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

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

2. Normative Reference

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

AWS A3.0:2001, *Standard Welding Terms and Definitions*.

Applications for copies should be addressed to Global Engineering Documents, 15 Inverness Way East, Englewood, Co 80112-5776, tel: 800-854-7179, website: global.ihs.com.

3. Terms and Definitions

The terms listed are used in various sections of this document and require definition for correct interpretation. Most of these terms are not contained in AWS A3.0-2001, *Standard Welding Terms and Definitions,* or if they are listed in AWS A3.0, their definitions have been enhanced to clarify their use in this document.

adjacent welds. Welds located next to each other joining the same pieces of metal.

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

edge weld. A weld located such that the electrode contact area as indicated by the weld indentation overlaps the edge of the sheet.

Governing Metal Thickness (GMT). The GMT for a two-sheet stackup is the metal thickness of the thinner of the two sheets. The GMT for a three-sheet stackup is the metal thickness of the second thickest sheet.

minimum weld size. The smallest allowable value for nugget width or the weld button.

minimum weld spacing. Minimum weld spacing is the shortest permissible distance or pitch from weld center to weld center of adjacent welds.

partial interfacial fracture. 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.

penetration. The height of the fusion zone expressed as a percent of the total material stack up welded.

set-up weld size. The set-up weld size is the weld size to be obtained during equipment set-up and when the electrodes are new.

weld aspect ratio. The weld aspect ratio is the ratio of the maximum diameter measurement to the minimum diameter measurement of the weld button.

weld group. A weld group is a row, string, pattern, or an array of spot welds joining one part to another. Weld groupings are identified on the product drawing.

4. General

4.1 Weld Process Control. Production welded parts that are joined by the resistance spot welding process have continually changing weld quality characteristics. Tolerances must be established for the required quality to be consistent with the manufacturing process capabilities. The welding process must be controlled to maintain (or exceed) minimum weld quality level that meets the product requirements. Information and guidance pertaining to supplier requirements for process and product control are contained in the *Quality System Requirements, QS-9000 Third Edition* or the latest edition of *ISO/TS 16949 Quality systems—Automotive suppliers—Particular requirements for the application of ISO 9001:2000*, published by the Automotive Industry Action Group (AIAG) (see Annex B).

4.2 Satisfactory Weld. A satisfactory weld has a nugget width or button (see 5.1.1) greater than or equal to the minimum weld size and satisfies the other criteria in Section 5, Weld Quality Evaluation Criteria. Tool design and set-up are based on a weld size larger than the minimum. As production welding continues, the weld size can vary down to the minimum value. When this deterioration becomes apparent, adjustment of the equipment or electrode maintenance, or both, is required to re-establish the weld dimensions near the set-up weld size.

4.3 Material Limitations. This recommended practice is limited to resistance spot welding applications using low carbon steel having a maximum yield strength of 420 MPa and a maximum carbon equivalent of 0.23 wt% (this corresponds to SAE 1010 steel of 0.13 wt% maximum carbon content). The carbon equivalent (C.E.) is calculated by the following formula:

$$C.E. = \%C + \%Mn/6 \qquad \text{Eq (1)}$$

4.3.1 Metallic Coatings. The following metallic coatings can be resistance spot welded:

(1) Zinc or zinc alloy coatings

(2) Terne coating

(3) Aluminum and aluminum alloy coatings

Coating type and thickness require careful attention to processing and equipment maintenance. Weldability decreases in the thinner base metal gages as the ratio of the coating to base metal thickness increases.

4.3.2 Paint and Other Nonmetallic Coatings. These coatings are acceptable provided welds meet the requirements of this recommended practice.

4.4 Surface Condition. The surface of the material at the time of welding should be free of contaminants that would adversely affect weld quality. The suitability of surface conditions should be ascertained in pre-production testing.

4.5 Weld Through Sealers and Adhesives. Sealers and adhesives are acceptable provided welds meet the requirements of this recommended practice.

4.6 Part Fit-Up. Mating parts should make contact at the faying surface with adequate fixturing and clamping, avoiding increases in electrode force. To assure good joint fit-up, all parts should be properly positioned and accurately located.

4.7 Weld Identification. Automotive manufacturers and suppliers use special symbols to identify a weld or group of welds. These symbols may be unique to each automotive manufacturer. The symbols are used to identify welds that require additional or special attention.

A listing of these symbols and their meanings are contained in Section II of the *Quality System Requirements, QS-9000 Third Edition* published by the Automotive Industry Action Group (AIAG).

5. Weld Quality Evaluation Criteria

5.1 Size. A satisfactory weld has a button size or nugget width greater than or equal to the minimum weld size shown in Table 1. The values in Table 1 are based on 4.0 times the square root of t (t = governing metal thickness).

5.1.1 The weld button (or plug) is that part of the weld joint that tears out in a peel or chisel test. The button size is the measurement of the maximum dimension (D_{MAX}) added to the measurement of the minimum dimension (D_{MIN}) and divided by 2 [Button Size = (D_{MAX} + D_{MIN})/2] (see Figure 1).

Table 1
Weld Sizes for Automotive Resistance Spot Welding

Governing Metal Thickness mm	Weld Size mm
0.60–0.79	3.5
0.80–0.99	4.0
1.00–1.19	4.5
1.20–1.59	5.0
1.60–1.99	5.5
2.00–2.39	6.0
2.40–2.79	6.5
2.80–3.19	7.0
3.20–3.59	7.5
3.60–3.99	8.0
4.00–4.39	8.5
4.40–5.00	9.0

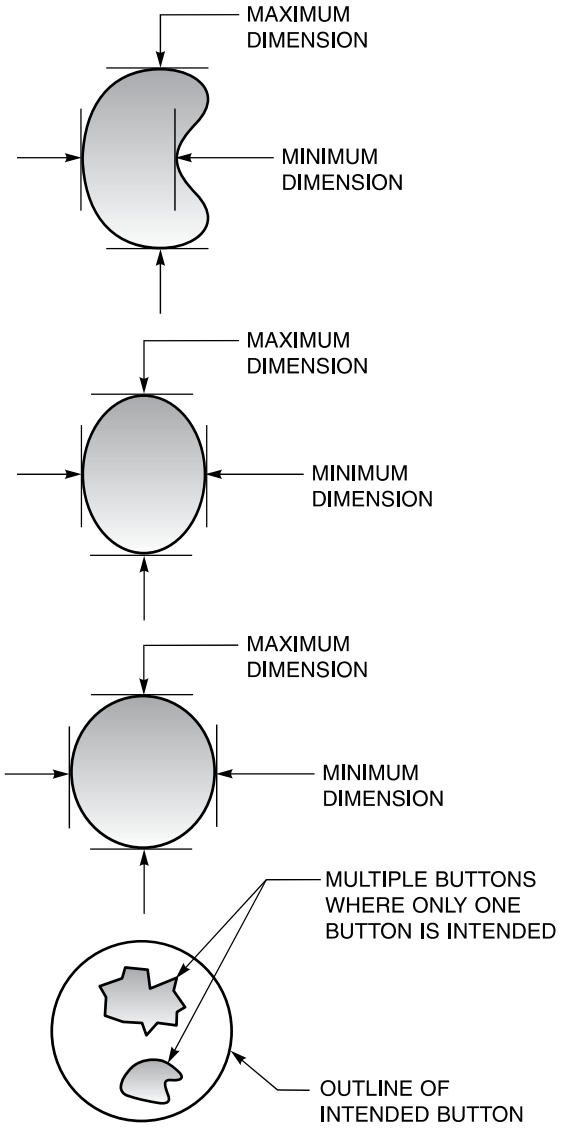


Figure 1—Measurement of Weld Size

5.1.2 The nugget width is the measure of the fusion zone in the plane of the faying surfaces from a cross-section (see Figure 2).

5.1.3 Weld Aspect Ratio. The weld aspect ratio for asymmetrical weld buttons should be 2.0 or less.

5.2 Location. A properly located weld has parent metal surrounding the electrode imprint and is placed within the dimensional tolerance allowed on the product drawing. If no location tolerance is specified, a weld is properly located provided the product resembles the weld locations indicated on the drawing. A typical tolerance for weld location is plus or minus 6.4 mm. Edge welds (Figure 3) and mislocated welds (Figure 4) are unacceptable.

5.3 Spacing. Spot welds that maintain minimum weld spacing as specified in a product drawing or equivalent are acceptable. Overlapping welds (Figure 5) or welds with insufficient spacing (Figure 6) are unacceptable.

5.4 Indentation. A weld with 30% or more electrode indentation depth in any sheet of the material stack up is not acceptable (see Figures 2 and 7).

5.5 Distortion. Welds that distort the sheet surfaces less than twice the governing metal thickness are acceptable (see Figure 8). Excessive distortion is unacceptable.

5.6 Weld Appearance. Welds with cracks, holes, and whiskers are unacceptable (see Figures 9 and 10).

5.7 Quantity. The number of acceptable welds in a weld group should equal the number of welds specified on the product drawing or be within the weld group quantity tolerance. Two adjacent unacceptable welds or an insufficient or an excessive quantity of acceptable welds in a group is unacceptable.

5.8 Penetration. Penetration is the ratio of the nugget's depth of fusion to the prewelded sheet thickness.

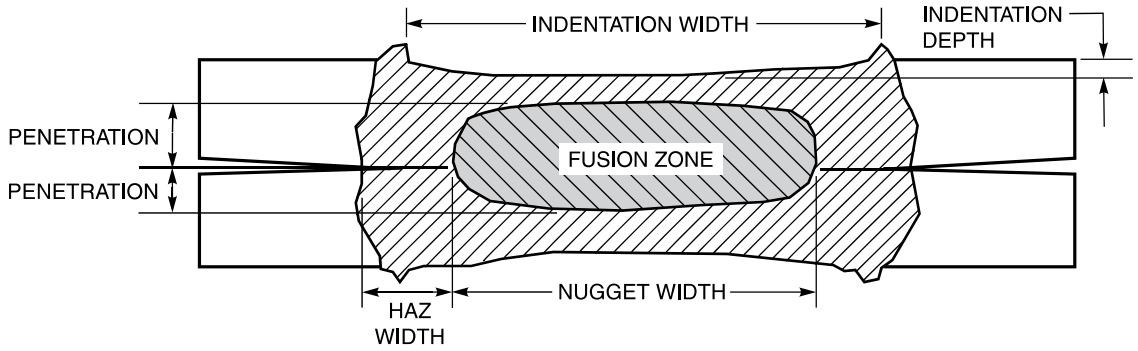


Figure 2—Attributes of a Spot Weld Measured from a Section Through the Center

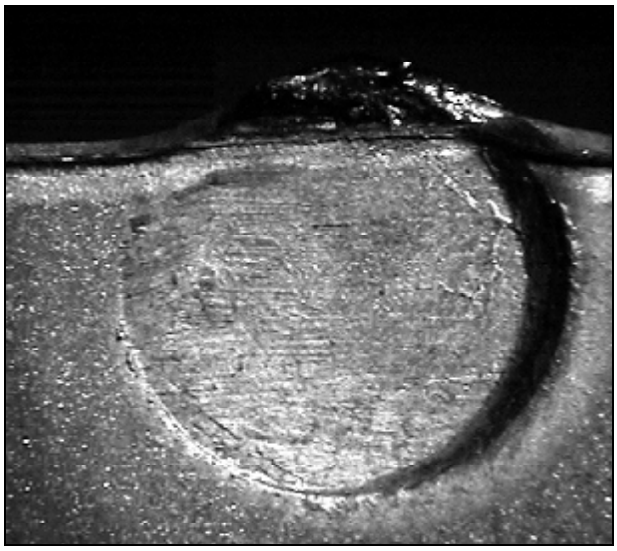


Figure 3—An Edge Weld

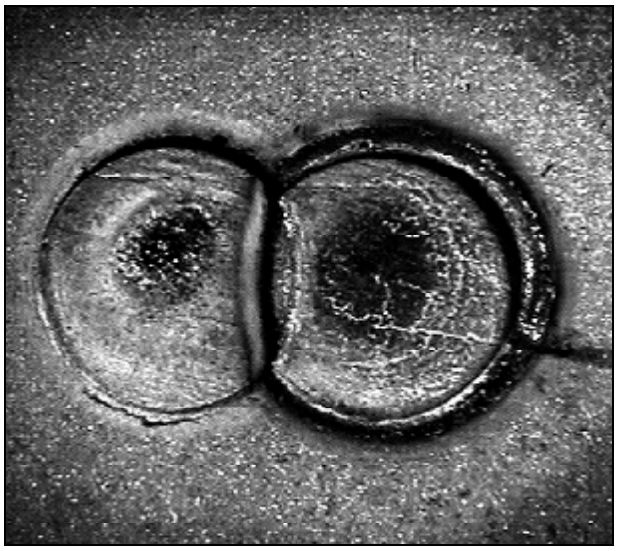


Figure 5—Overlapped Welds

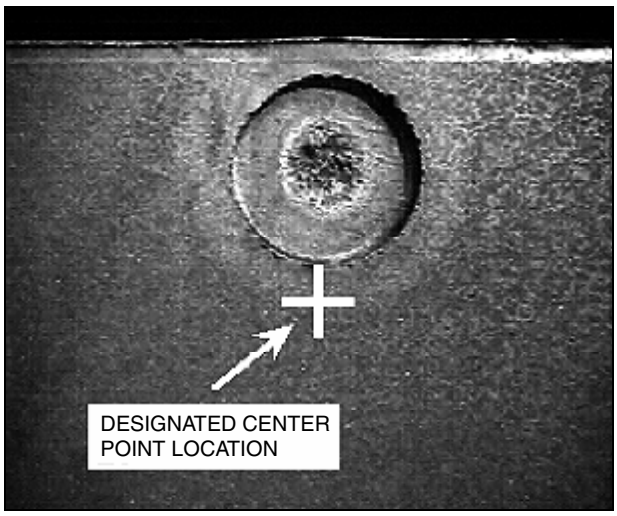


Figure 4—A Mislocated Weld

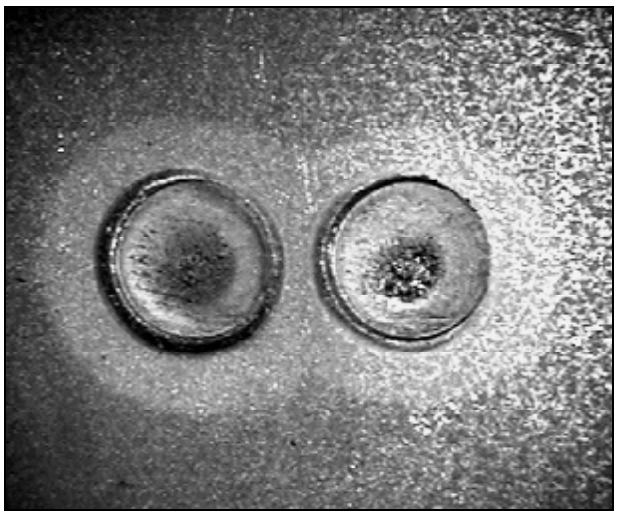


Figure 6—Potentially Insufficient Spaced Welds

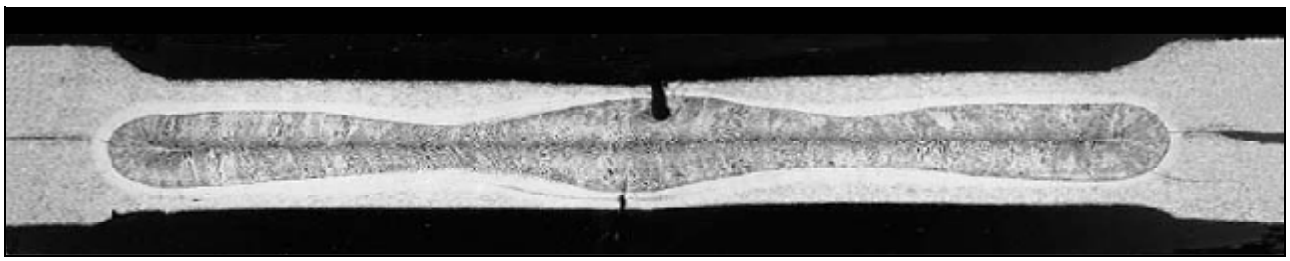


Figure 7—Excessive Indentation

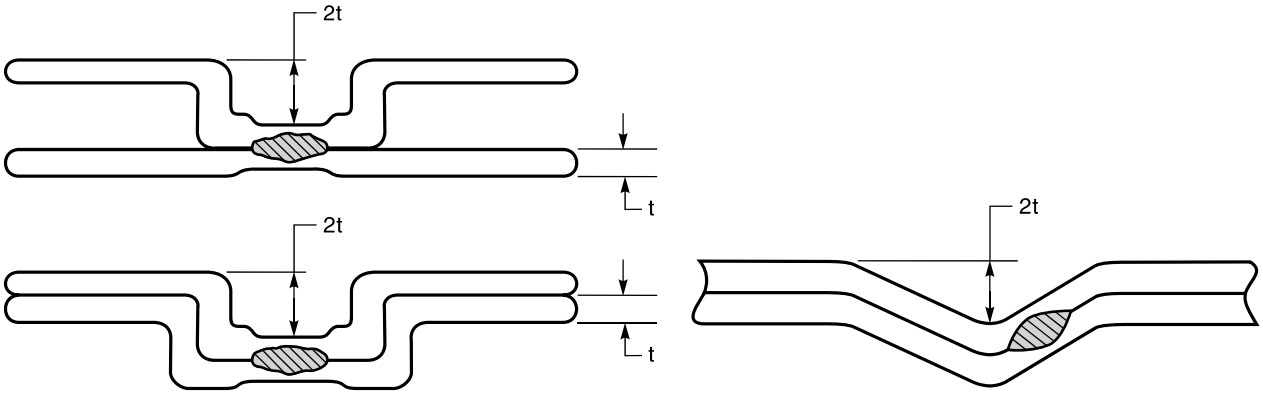


Figure 8—Weld Distortion

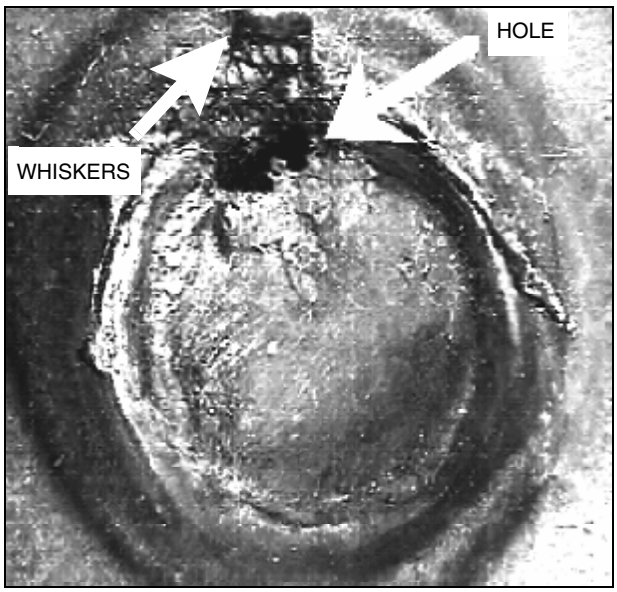


Figure 9—Holes and Whiskers on a Weld Surface

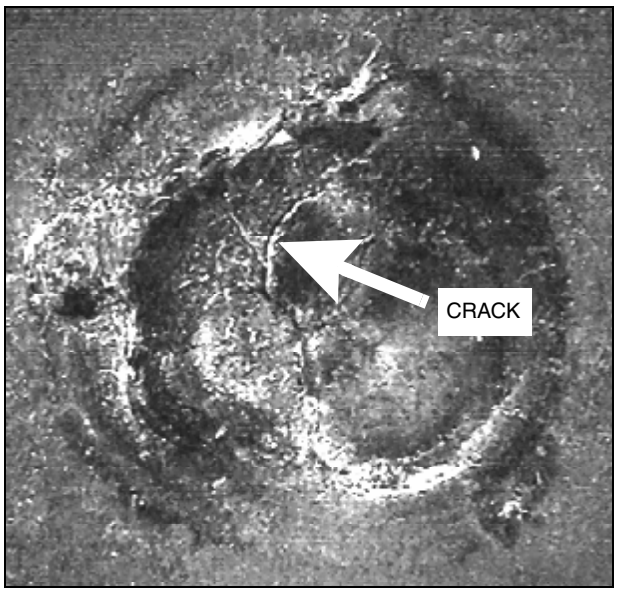


Figure 10—Surface Cracks

Penetration is expressed as a percentage and is calculated for each sheet thickness. Penetration must exceed 20% of the prewelded sheet thickness into each sheet of the weldment (see Figure 2).

6. Inspection Techniques

6.1 Visual Evaluation. Some weld variations such as edge welds (Figure 3), mislocation (Figure 4), overlapping welds (Figure 5), insufficient spacing (Figure 6), excessive indentation (Figure 7), excessive distortion, cracks (Figure 10), and holes (Figure 9) can be detected visually. Visual acceptance criteria are to be consistent with requirements in Section 5, Weld Quality Evaluation Criteria. Visual inspection should not be a substitute for destructive testing.

6.2 Nondestructive Testing. Nondestructive testing includes those inspection methods that permit evaluation of welds without destroying their usefulness. Nondestructive methods employed by the automotive industry include ultrasonic, resistivity, and deformation testing of the product. Application of nondestructive methods should be carefully evaluated prior to use. Nondestructive test methods are not intended to replace destructive tests.

6.3 Destructive Testing

6.3.1 Production Parts. Spot welds on production parts should be tested for the required size after the completion of all spot welding on the assembly or subassembly. Destructive testing should be made on as small a spot welded production unit as is practical.

6.3.2 Coupons. The dimensions of the test specimen can affect the results of weld quality evaluation or test conducted on coupons. To ensure the consistency of testing, standard sized specimens should be used in instrumented tests for both static and dynamic testing. Recommended specimen sizes for static tensile-shear tests can be found in Table 2. The length of a single coupon is 150 mm or more for all gauges, and the overlap is the same as the width. Standard specimen sizes for impact tests can be found in Table 3 with dimensions indicated in Figure 11.

7. Test Methods

7.1 Peel Test. The peel test (Figure 12) consists of peeling apart, to destruction, a weld sample to determine the weld button size and weld fracture mode. Depending on the material and type of loading, a button may not always result from peel testing. In the case of an interfacial fracture, macro section examination of the fusion zone must be used to determine acceptability. A spot weld is considered acceptable if the peel test reveals a weld button size greater than or equal to values from Table 1 Weld Sizes for Automotive Resistance Spot Welding.

Table 2
Minimum Width for
Tensile-Shear Testing Specimens

Thickness mm	Width mm
0.50–0.99	35.00
1.00–1.49	40.00
1.50–1.99	50.00
2.00–2.49	60.00
2.50–2.99	70.00
3.00–3.49	80.00
3.50–3.99	90.00
4.00–4.49	100.00
4.50–5.00	110.00

Table 3
Minimum Width for
Impact Testing Specimens

Thickness mm	Width mm
0.50–1.49	50.00
1.50–2.49	60.00
2.50–3.49	70.00
3.50–4.49	80.00
4.50–5.00	90.00

7.2 Chisel Test. A chisel test consists of forcing a tapered chisel into the lap on each side of the weld being tested until the weld or the joint separates resulting in a pulled button or interfacial failure. The edges of the chisel must not touch the weld being tested (see Figure 13). This type of test should be used when a peel test is not practical. The weld acceptance is based on the same criteria as for the peel test.

7.3 Metallographic Test. A metallographic test is used to determine the weld nugget width, penetration, indentation, and heat-affected zone width (Figure 2). It can also be used to detect cracks, porosity (Figure 14), and nonmetallic inclusions. In this test, weld sections are cut from product samples, polished to the weld centerline, chemically etched to reveal the microstructure, and then optically examined. An acceptable weld has a fusion zone equal to or greater than the values from Table 1 Weld Sizes for Automotive Resistance Spot Welding. Requirements for metallographic examination of spot welds should be specified on the product drawing or in the process control plan.

7.4 Tensile-Shear Test. A tensile-shear test is a quasi-static test by pulling lap-joined specimens (Figure 15) on a tensile testing machine. To minimize the influence of pulling speed, the test should be conducted at a speed of at most 15 mm/min. Shimming at the grips is needed to avoid excessive bending of the specimen if the thicker sheet is more than 1.5 mm. The metrics that can be monitored include the peak value of load (peak load), displacement up to the peak load, energy defined by the area under the load-displacement curve up to the peak load (Figure 16), and failure mode (Figure 17).

7.5 Double Pendulum Impact Test. This impact test refers to the impacting of lap-joined specimens using an impact tester (see Figure 18). This test intends to quantify a weld's dynamic performance. Both impact energy and weld failure mode should be recorded. The impact performance of a weld can usually be categorized as "ductile" (with relatively high impact energy) or "brittle" (with relatively low impact energy) for a particular material. A spot weld is considered acceptable if its impact energy falls in the "ductile" group.

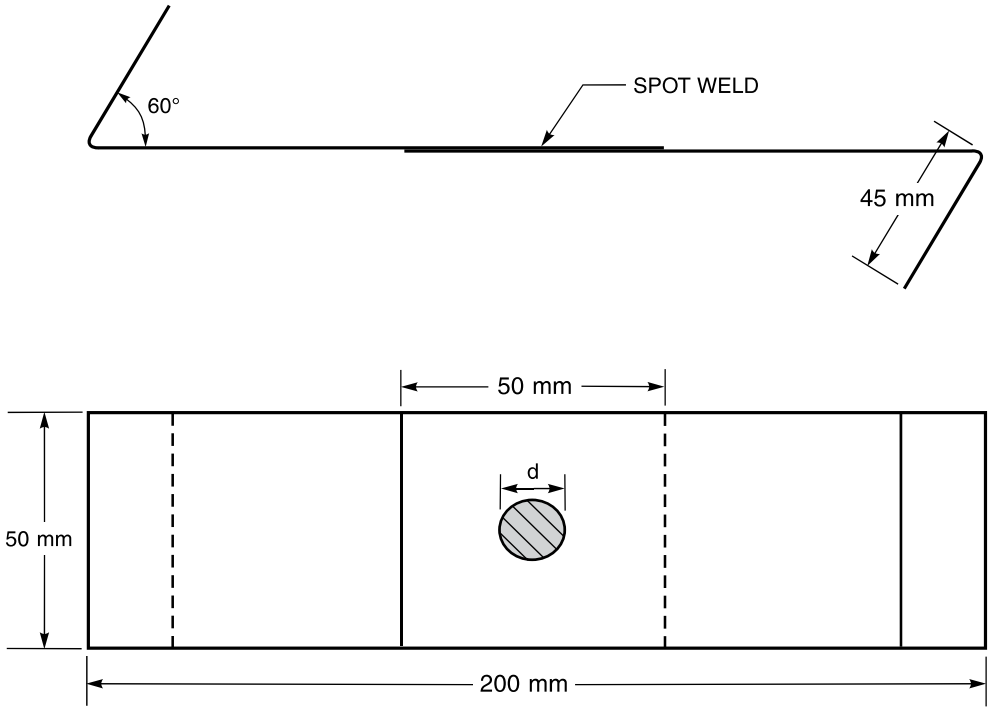


Figure 11—Impact Testing Specimen Dimensions

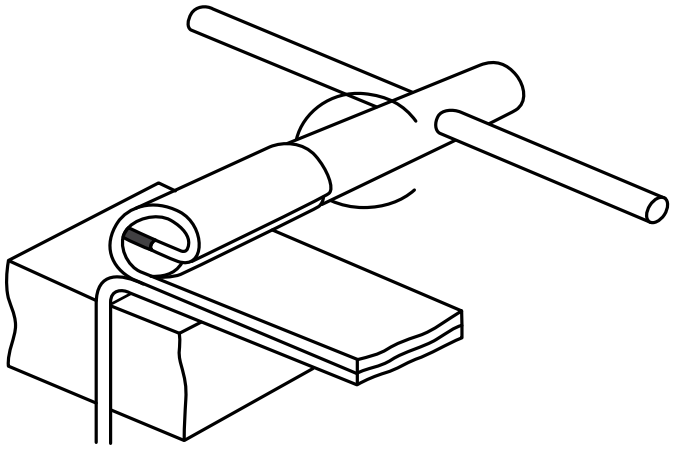


Figure 12—Peel Test

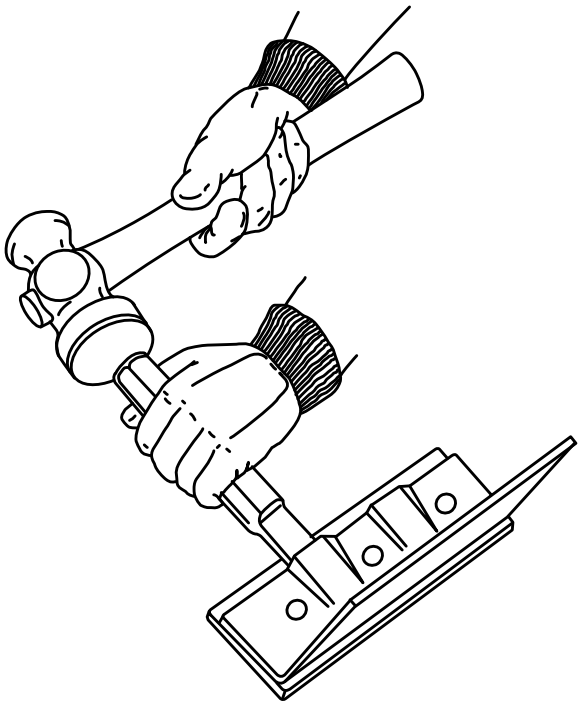


Figure 13—Chisel Test

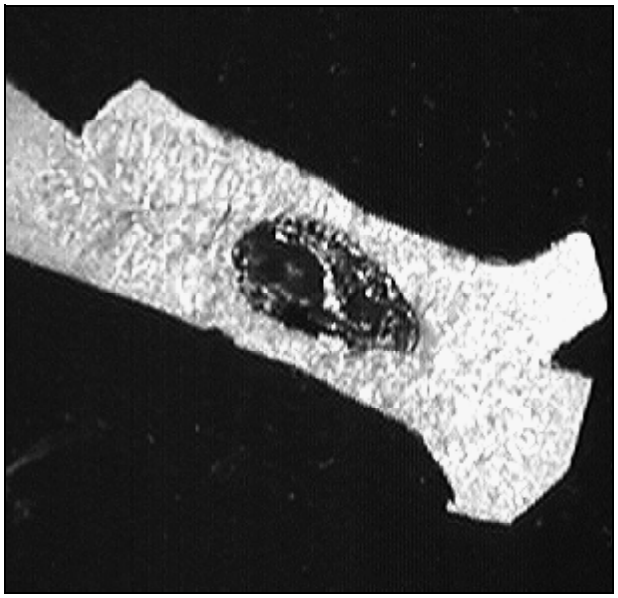


Figure 14—Porosity in a Weld Revealed in a Cross Section

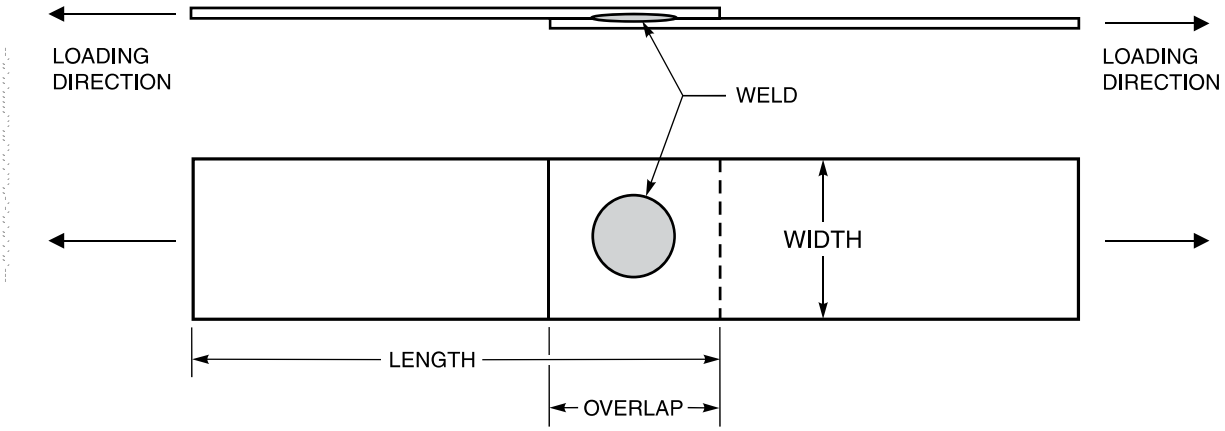


Figure 15—Tensile-Shear Test

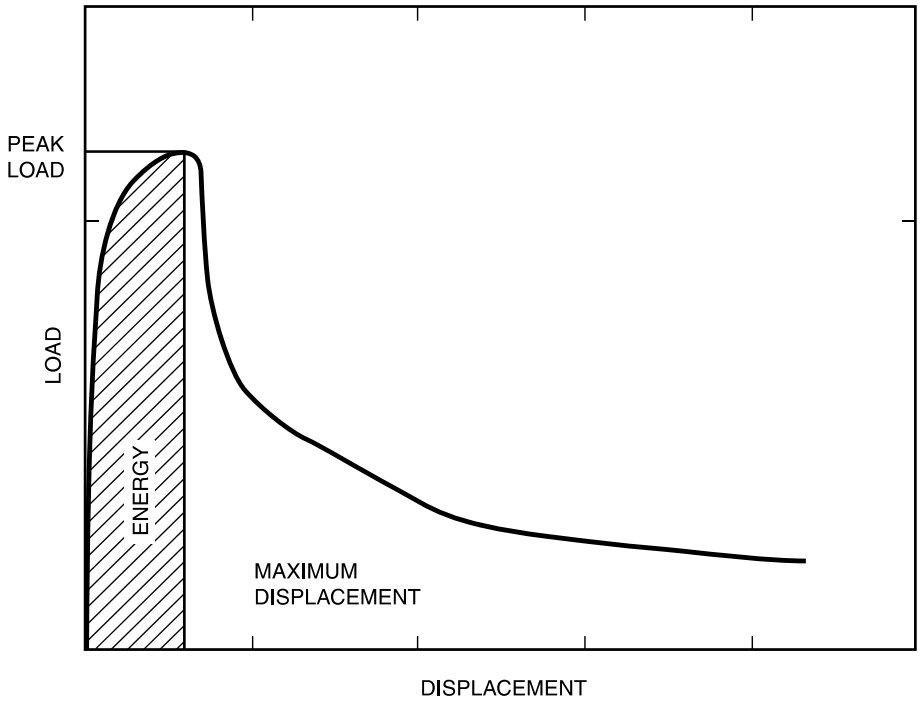


Figure 16—Quantities to be Measured in a Tensile-Shear Test

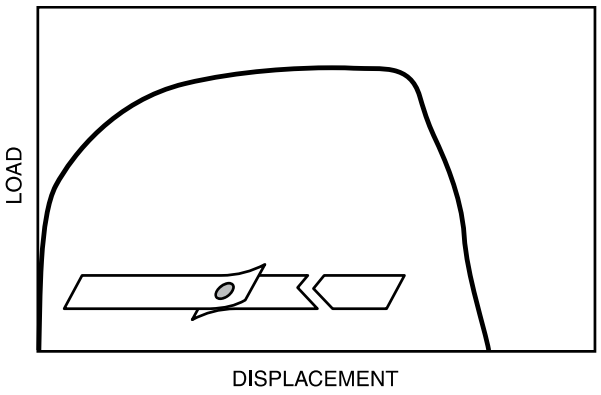
7.6 Other Tests. Additional test methodologies are contained in AWS C1.1M/C1.1:2000, *Recommended Practices for Resistance Welding*.

8. Disposition of Substandard Products

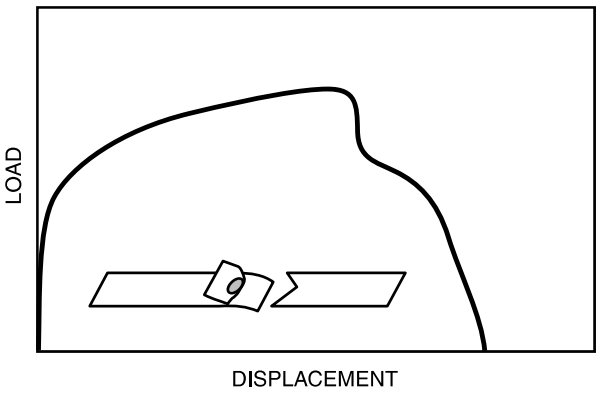
Products that do not conform to the requirements of this recommended practice should be rejected. The disposition or method of repair of these products should be approved by the manufacturer's quality control, other approvals the manufacturer may designate, or some combination of these.

9. Safety

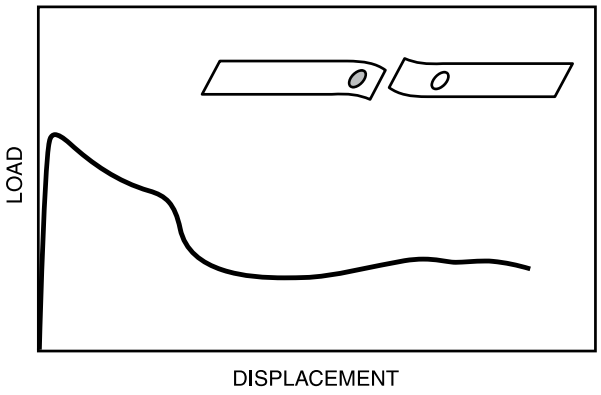
Welding, cutting, and allied processes can be performed safely with minimal health risk, provided proper procedures are followed and necessary precautions are taken. An informative reference that provides guidance for personnel in the safe set-up and use of welding and cutting equipment is the ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*.



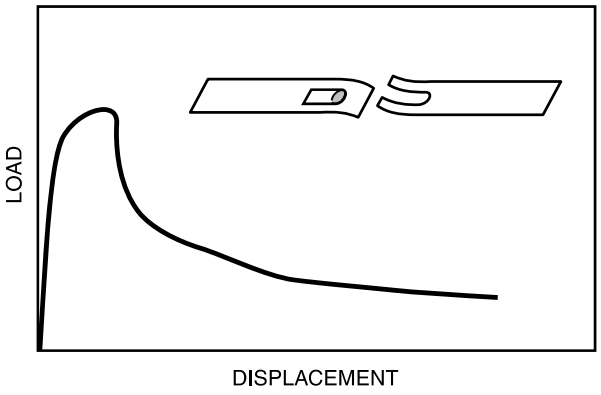
(A) Base Metal Failure in Tension-Shear Test



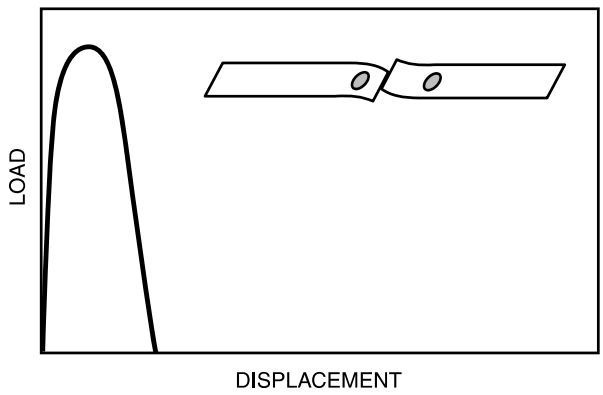
(B) Failure Partially Through Base Metal in Tension-Shear Test



(C) Weld Button Pull-Out in Tension-Shear Test



(D) Tear-Off of Base Metal in Tension-Shear Test



(E) Interfacial Failure in Tension-Shear Test

Figure 17—Tensile-Shear Test Failure Mode

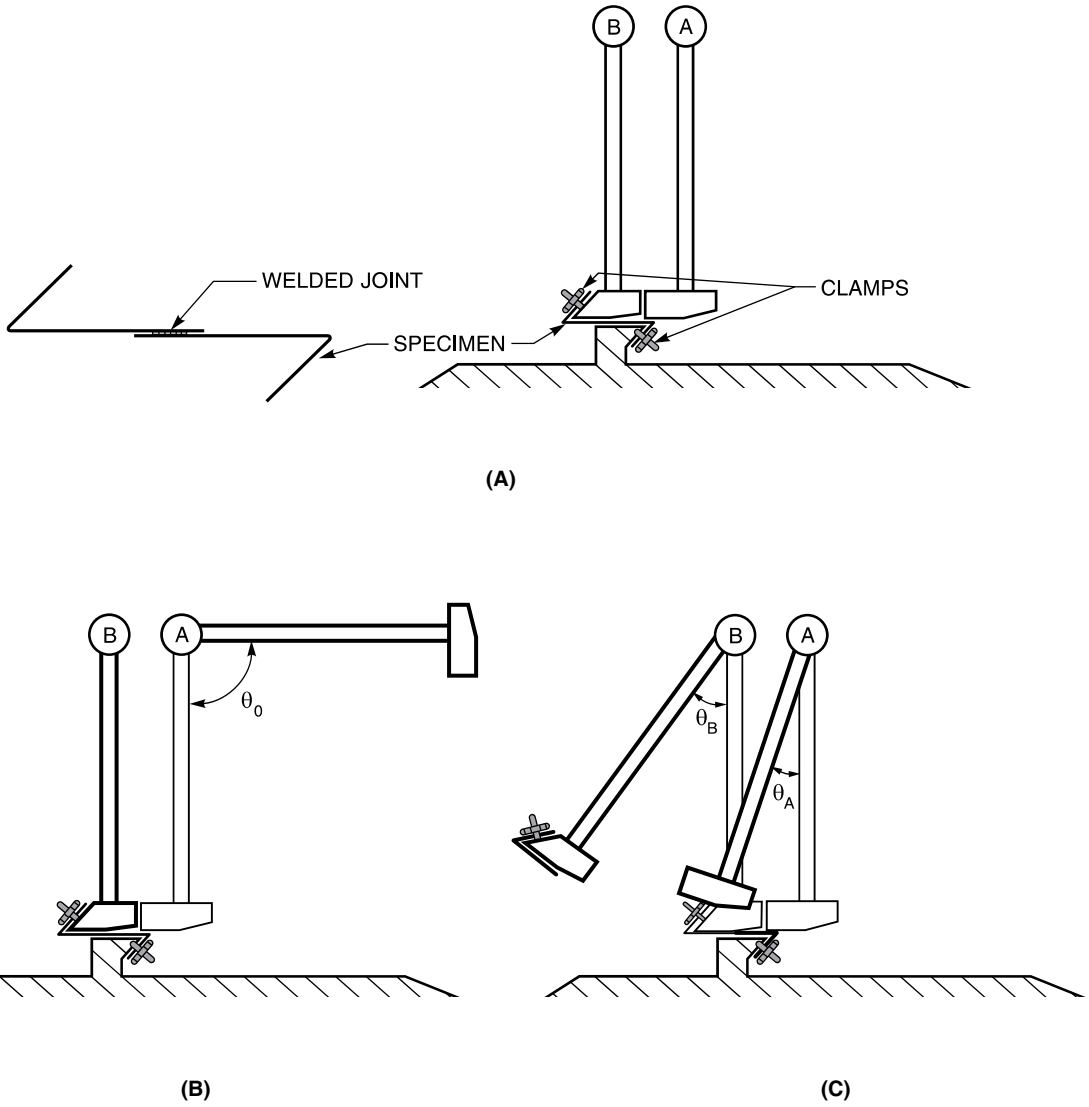


Figure 18—Double Pendulum Impact Test

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Nonmandatory Annexes

Annex A

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS D8.7M:2005, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, but is included for informational purposes only.)

A1. Introduction

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

A2. Procedure

All inquiries must be directed to:

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

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

A2.1 Scope. Each inquiry must address one single provision of the standard, unless the point of the inquiry involves two or more interrelated provisions. That provision must be identified in the scope of the inquiry, along with the edition of the standard that contains the provisions or that the inquirer is addressing.

A2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a standard requirement, or to request the revision of a particular provision in the standard.

A2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry must provide technical justification for that revision.

A2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

A3. Interpretation of Provisions of the Standard

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

A4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal*.

A5. Telephone Inquiries

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

A6. The AWS Technical Committee

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

Annex B

Reference Documents

(This Annex is not a part of AWS D8.7M:2005, *Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*, but is included for informational purposes only.)

B1. AWS Documents

(1) ANSI Z49.1:1999, *Safety in Welding, Cutting, and Allied Processes*; and

(2) AWS C1.1M/C1.1:2000, *Recommended Practices for Resistance Welding*.

(Available from Global Engineering Documents, 15 Inverness Way East, Englewood, Co 80112-5776, tel: 800-854-7179, website: global.ihs.com.)

B2. Quality System Requirements, QS-9000 Third Edition

This document is the Worldwide Quality Systems Requirement for automotive suppliers. It was developed by Chrysler, Ford, and General Motors, and includes the complete contents of ISO 9001.

(Available from the Automotive Industry Action Group, AIAG, Dept. 77839, P.O. Box 77000, Detroit, Michigan 48277.)

B3. ISO/TS 16949 Quality Systems—Automotive Suppliers—Particular Requirements for the Application of ISO 9001:2000

This document combines the requirements of European and American automakers into a single specification. It applies to the design, development, installation, and servicing of automotive products.

(Available from the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.)

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List of AWS Documents on Automotive Welding

Designation	Title
D8.6-77	*Standard for Automotive Resistance Spot—Welding Electrode*
D8.7-88	*Recommended Practices for Automotive Weld Quality—Resistance Spot Welding*
D8.8-97	*Specification for Automotive Frame Welding Quality—Arc Welding*
D8.9M:2002	*Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*
D8.14M/D8.14	*Specification for Automotive and Light Truck Components Weld Quality—Aluminum Arc Welding*

For ordering information, contact Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, Colorado 80112-5776; telephones: (800) 854-7179, (303) 397-7956; fax (303) 397-2740; Internet: www.global.ihs.com.

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