

**AWS A5.24/A5.24M:2005**  
**An American National Standard**

# **Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods**



**American Welding Society**



**Key Words**—Zirconium alloy wire, zirconium welding electrodes, zirconium welding rods, gas metal arc welding, gas tungsten arc welding, plasma arc welding

**AWS A5.24/A5.24M:2005**  
**An American National Standard**

**Approved by**  
**American National Standards Institute**  
**October 28, 2004**

# **Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods**

**Supersedes ANSI/AWS A5.24-90R**

Prepared by  
AWS A5 Committee on Filler Metals and Allied Materials

Under the Direction of  
AWS Technical Activities Committee

Approved by  
AWS Board of Directors

## **Abstract**

This specification prescribes the requirements for classification of zirconium and zirconium alloy electrodes and rods for GTA, GMA, and PA welding. AWS A5.24/A5.24M:2005 is a revision of the zirconium welding electrode document last revised in 1990. The compositions specified for each classification represent the latest state-of-the-art. Additional requirements are included for testing procedures, manufacture, sizes, lengths, and packaging. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of the zirconium alloy filler metal.

This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these are not equivalent, each system must be used independently of the other.

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**American Welding Society**

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\*Advisor

\*\*Deceased

\*\*\*Special Contributor

## Foreword

(This Foreword is not a part of AWS A5.24/A5.24M:2005, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*, but is included for informational purposes only.)

This document is the first of the A5.24 specifications which makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way when referring to filler metal properties. In selecting rational metric units, the *Metric Practice Guide for the Welding Industry* (AWS A1.1) and International Standard ISO 544, *Welding consumables—Technical delivery conditions for welding filler metals—Type of product, dimensions, tolerances, and markings*, are used where suitable. Tables and figures make use of both U.S. Customary and SI Units, which with the application of the specified tolerances provides for interchangeability of products in both the U.S. Customary and SI Units.

AWS A5.24:2005, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*, is the third revision of the document issued initially in 1976. Other than the deletion of the ERZr1 classification in 1979 and the check analysis tolerances in 1990, there has been no major change in the requirements of the specification over the past several years. With this revision, information concerning the **Acceptance** and **Certification** clauses has been added to Annex A.

Previous editions of the document are as follows:

ANSI/AWS A5.24-76, Specification for Zirconium and Zirconium Alloy Bare Welding Rods and Electrodes

ANSI/AWS A5.24-79, Specification for Zirconium and Zirconium Alloy Bare Welding Rods and Electrodes

ANSI/AWS A5.24-90, Specification for Zirconium and Zirconium Alloy Bare Welding Rods and Electrodes

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, 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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# Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods

## 1. Scope

**1.1** This specification prescribes requirements for the classification of zirconium and zirconium-alloy electrodes and rods for gas tungsten arc, gas metal arc, and plasma arc welding.

**1.2** Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in the nonmandatory Annex Sections A5 and A9. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

**1.3** This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to filler metal properties. The specification with the designation A5.24 uses U.S. Customary Units. The specification A5.24M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of electrodes or packaging or both under the A5.24 or A5.24M specifications.

## 2. Normative References

**2.1** The following ANSI/AWS standards<sup>1</sup> are referenced in the mandatory sections of this document:

- (1) AWS A5.01, *Filler Metal Procurement Guidelines*

1. AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, Colorado 80112-5776; telephone: (800) 854-7179, (303) 397-2740; fax: 9303) 397-2740; Internet:www.global.ihs.com.

- (2) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

**2.2** The following ASTM standards<sup>2</sup> are referenced in the mandatory sections of this document:

- (1) ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

- (2) ASTM E 146, *Standard Methods for Chemical Analysis of Zirconium and Zirconium-Base Alloys*

**2.3** The following ISO standard<sup>3</sup> is referenced in the mandatory sections of this document:

- (1) ISO 544, *Welding consumables—Technical delivery conditions for welding filler metals—Type of product, dimensions, tolerances, and markings*

## 3. Classification

**3.1** The welding materials covered by the A5.24/A5.24M specification are classified using a system that is independent of U.S. Customary Units and the International System of Units (SI). Classification is according to chemical composition as specified in Table 1.

**3.2** Materials classified under one classification shall not be classified under any other classification of this specification. An electrode or rod may be classified under both A5.24 and A5.24M providing it meets the requirements of both specifications.

**3.3** The filler metals classified under this specification are intended for gas tungsten arc, gas metal arc, and plasma arc welding processes, but that is not to prohibit

2. ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

3. ISO standards can be obtained from the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

**Table 1**  
**Chemical Composition Requirements for**  
**Zirconium and Zirconium-Alloy Electrodes and Rods**

| Weight Percent <sup>a</sup> |                            |                           |         |                       |         |                     |                       |                       |                     |                        |
|-----------------------------|----------------------------|---------------------------|---------|-----------------------|---------|---------------------|-----------------------|-----------------------|---------------------|------------------------|
| AWS<br>Classifi-<br>cation  | UNS<br>Number <sup>b</sup> | Zirconium<br>+<br>Hafnium | Hafnium | Iron<br>+<br>Chromium | Tin     | Oxygen <sup>c</sup> | Hydrogen <sup>c</sup> | Nitrogen <sup>c</sup> | Carbon <sup>c</sup> | Niobium<br>(Columbium) |
| ERZr2                       | R60702                     | 99.0 min                  | 4.5     | 0.20                  | —       | 0.11–0.15           | 0.005                 | 0.015                 | 0.03                | —                      |
| ERZr3                       | R60704                     | 97.5 min                  | 4.5     | 0.20–0.40             | 1.0–2.0 | 0.11–0.16           | 0.005                 | 0.015                 | 0.03                | —                      |
| ERZr4                       | R60705                     | 95.5 min                  | 4.5     | 0.20                  | —       | 0.11–0.16           | 0.005                 | 0.015                 | 0.03                | 2.0–3.0                |

a. Single values are maximum, except as noted.

b. SAE HS-1086 *Metals & Alloys in the Unified Numbering System*. Document may be obtained from SAE International 400 Commonwealth Dr., Warrendale, PA 15096-0001, USA; Phone: (724) 776-4841; fax: (724) 776-5760; e-mail: publication@sae.org; Website: www.sae.org.

c. Analysis of the interstitial elements C, O, H, and N shall be conducted on samples of filler metal taken after the filler metal has been reduced to its final diameter and all processing operations have been completed. Analysis of the other elements may be conducted on these same samples or it may have been conducted on samples taken from the ingot or the rod stock from which the filler metal is made. In case of dispute, samples from the finished filler metal shall be the referee method.

their use with any other process for which they are found suitable.

ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.

## 4. Acceptance

Acceptance<sup>4</sup> of the electrode or rod shall be in accordance with the provisions of AWS A5.01, *Filler Metal Procurement Guidelines*.

## 5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.<sup>5</sup>

## 6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the “nearest unit” in the last right-hand place of figures used in expressing the limiting value in accordance with the rounding-off method given in

4. See Section A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and A5.01, *Filler Metal Procurement Guidelines*.

5. See Section A4, Certification (in Annex A) for further information concerning certification and the testing specified to meet this requirement.

## 7. Summary of Tests

7.1 The only test required for classification of a product under this specification is full chemical analysis of the filler metal after all thermal and chemical processing or, as permitted in footnote c to Table 1, partial chemical analysis of the rod stock or original producer’s melt being used to produce such filler metal together with partial chemical analysis of the finished filler metal when analyzing for interstitial elements, C, H, O, and N.

## 8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material for retest may be taken from the original sample or from a new sample. Retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the materials under test shall be considered as not meeting the requirements of this specification.

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the test specimens or in conducting the test, the test shall be considered invalid, without regard to whether the test was

actually completed, or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

## 9. Chemical Analysis

**9.1** A sample of the filler metal, or the stock from which it is made, shall be prepared for chemical analysis except as provided in Table 1, footnote c.

**9.2** The sample shall be analyzed by accepted analytical methods.

**9.3** The results of the analysis shall meet the requirements of Table 1, for the classification of filler metal under test.

## 10. Method of Manufacture

The welding electrodes and rods classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

## 11. Standard Sizes and Lengths

Standard sizes for electrodes and rods in different package forms (straight lengths, coils with support, coils without support, and spools) are shown in Table 2.

## 12. Finish and Uniformity

**12.1** All electrodes and rods shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps, and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

**12.2** Each continuous length of filler metal shall be from a single heat of material, and welds, when present, shall have been made so as not to interfere with uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

## 13. Standard Package Forms

**13.1** Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard package dimensions and weights for each form are given in Table 3. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

**Table 2**  
**Standard Sizes and Lengths<sup>a</sup>**

| Standard Package Forms                                                       | Diameter |                         |                  | Tolerances |              |
|------------------------------------------------------------------------------|----------|-------------------------|------------------|------------|--------------|
|                                                                              | in       | decimal in <sup>b</sup> | mm               | in         | mm           |
| Straight Lengths <sup>c</sup><br>Coils without Support<br>Coils with Support | 1/16     | 0.062                   | 1.6              | ±0.002     | +0.01, -0.04 |
|                                                                              |          | 0.079                   | 2.0              | ±0.002     | +0.01, -0.04 |
|                                                                              |          | 0.094                   | 2.4              | ±0.002     | +0.01, -0.04 |
|                                                                              |          | 0.098                   | 2.5 <sup>d</sup> | ±0.002     | +0.01, -0.04 |
|                                                                              | 1/8      | 0.125                   | 3.2              | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.156                   | 4.0              | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.188                   | 4.8 <sup>d</sup> | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.197                   | 5.0              | ±0.002     | +0.01, -0.07 |
| Spools                                                                       | 3/16     | 0.197                   | 5.0              | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.25                    | 6.4 <sup>d</sup> | ±0.002     | +0.01, -0.07 |
|                                                                              | 1/4      | 0.25                    | 6.4 <sup>d</sup> | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.312                   | 7.9              | ±0.002     | +0.01, -0.07 |
|                                                                              | 5/16     | 0.312                   | 7.9              | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.375                   | 9.5              | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.437                   | 11.1             | ±0.002     | +0.01, -0.07 |
|                                                                              |          | 0.475                   | 12.0             | ±0.002     | +0.01, -0.07 |

Notes:

a. Dimensions, tolerances, and package forms (for round filler metal) other than those shown shall be as agreed by purchaser and supplier.

b. Decimal inch are exact conversions with appropriate rounding.

c. Length shall be 36 in ± 1/4 in [900 mm ± 5 mm]

d. Not shown as standard metric size in ISO 544.

**Table 3**  
**Standard Packages,**  
**Dimensions, and Weights**

| Package Form          | Nominal<br>Net Weight |     |       |      |
|-----------------------|-----------------------|-----|-------|------|
|                       | lb                    | kg  |       |      |
| Straight Lengths      | 5                     | 2.5 |       |      |
|                       | 10                    | 5   |       |      |
|                       | 25                    | 10  |       |      |
|                       | 50                    | 25  |       |      |
| Coils without Support | 25                    | 10  |       |      |
| Coils with Support    | 50                    | 25  |       |      |
|                       | 60                    | 30  |       |      |
| Spools                | in                    | mm  |       |      |
|                       | 4                     | 100 | 1     | 0.5  |
|                       | 8                     | 200 | 5     | 2.5  |
|                       | 12                    | 300 | 10–26 | 5–12 |
|                       | 13-1/2                | 340 | 30    | 15   |

**General Notes:**

1. Filler metal diameters for all forms and lengths are given in Table 2.
2. No more than one classification or size shall be included in each package.
3. Dimensions of coils shall be as agreed by purchaser and supplier.
4. Dimensions of standard spools are shown in Figure 1.

**13.2** The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use, and shall be clean and dry enough to maintain the cleanliness of the filler metal.

**13.3** Spools (Figure 1) shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

## 14. Winding Requirements

**14.1** Filler metal in coils and on spools shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the electrode (the end with which welding is to begin with) shall be identified so it can be located readily and shall be fastened to avoid unwinding. The winding shall be level winding.

**14.2** The cast and helix of filler metal in coils and on spools shall be such that the filler metal will feed in an

uninterrupted manner in automatic and semiautomatic equipment.

**14.2.1** The cast and helix of filler metal on 4 in [100 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 2.5 in [65 mm] nor more than 9 in [230 mm] in diameter, and

(2) rise above the flat surface no more than 0.5 in [13 mm] at any location.

**14.2.2** The cast and helix of filler metal on 8 in [200 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 10 in [250 mm] nor more than 20 in [510 mm] in diameter, and

(2) rise above the flat surface no more than 0.75 in [19 mm] at any location.

**14.2.3** The cast and helix of filler metal on 12 in [300 mm] spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) form a circle not less than 15 in [380 mm] nor more than 30 in [760 mm] in diameter, and

(2) rise above the flat surface no more than 1 in [25 mm] at any location.

## 15. Filler Metal Identification

**15.1** The product information and the precautionary information required in Section 17 for marking each package shall appear also on each coil and spool.

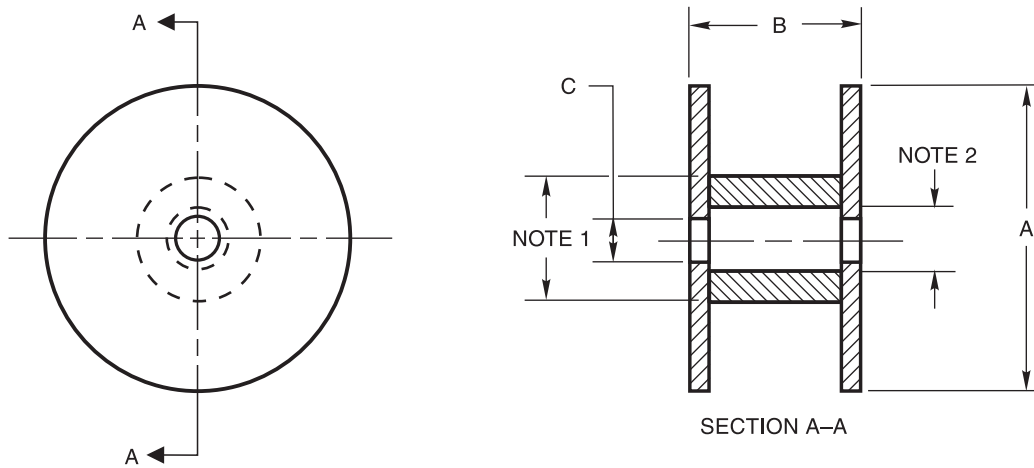
**15.2** Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

**15.3** Coils with support shall have the information securely affixed in a prominent location on the support.

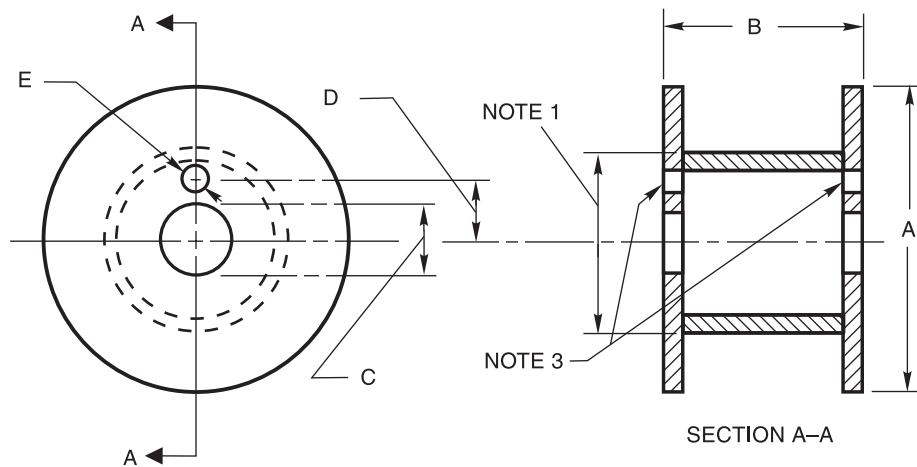
**15.4** Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

## 16. Packaging

Electrodes and rods shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.



DIMENSIONS OF STANDARD 4 in [100 mm] SPOOL



DIMENSIONS OF STANDARD 8 AND 12 in [200 AND 300 mm] SPOOLS

|   |                                    | 4 in [100 mm]     |              | 8 in [200 mm]     |                  | 12 in [300 mm]    |                  |
|---|------------------------------------|-------------------|--------------|-------------------|------------------|-------------------|------------------|
|   |                                    | in                | mm           | in                | mm               | in                | mm               |
| A | Diameter, max. (Note 4)            | 4.0               | 102          | 8.0               | 203              | 12                | 305              |
| B | Width<br>Tolerance                 | 1.75<br>±0.03     | 45<br>+0, -2 | 2.16<br>±0.03     | 55<br>+0, -3     | 4.0<br>±0.06      | 16.5<br>+0, -3   |
| C | Diameter<br>Tolerance              | 0.63<br>+0.01, -0 | 16<br>+1, -0 | 2.03<br>+0.06, -0 | 50.5<br>+2.5, -0 | 2.03<br>+0.06, -0 | 50.5<br>+2.5, -0 |
| D | Distance between axes<br>Tolerance | —<br>—            | —<br>—       | 1.75<br>±0.02     | 44.5<br>±0.5     | 1.75<br>±0.02     | 44.5<br>±0.5     |
| E | Diameter (Note 3)<br>Tolerance     | —<br>—            | —<br>—       | 0.44<br>+0, -0.06 | 10<br>+1, -0     | 0.44<br>+0, -0.06 | 10<br>+1, -0     |

## Notes:

1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in [100 mm] spools.
4. Metric dimensions and tolerances conform to ISO 544 except that "A" specifies  $\pm$  tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

**Figure 1—Dimensions of 4, 8, and 12 in [100, 200, and 300 mm] Diameter Spools**

## 17. Marking of Packages

**17.1** The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package:

- AWS specification (year of issue may be excluded) and AWS classification numbers.
- Supplier's name and trade designation
- Size and net weight
- Lot, control, or heat number

**17.2** The appropriate precautionary information<sup>6</sup> as given in ANSI Z49.1, latest edition (as a minimum), shall be prominently displayed in legible print on all packages of welding material, including individual unit packages enclosed within a larger package.

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6. Typical examples of "warning labels" are shown in figures in ANSI Z49.1, for some common or specific consumables used with certain processes.

## Nonmandatory Annexes

### Annex A

## Guide to AWS Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods

(This Annex is not a part of AWS A5.24/A5.24M:2005, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*, but is included for informational purposes only.)

### A1. Introduction

The purpose of this guide is to correlate the filler metal classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each filler metal is suitable.

### A2. Classification System

**A2.1** The system for identifying the filler metal classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter

“E” at the beginning of each classification designation stands for electrode, and the letter “R” stands for welding rod. Since these filler metals are used as electrodes in gas metal arc welding and as rods in gas tungsten arc welding, both letters are used.

**A2.2** The chemical symbol “Zr” appears after “R” as a means of identifying the filler metals as unalloyed zirconium or a zirconium-base alloy. The numeral provides a means of identifying different variations in the composition.

**A2.3** Table A1 provides a correlation of the classifications in this revision with those in earlier (1990, 1979, 1976) revisions and with other specifications for zirconium alloy filler metals. The ASTM/ASME Specifications listed are also widely used in industry as shown in Table A1.

**Table A1**  
**Specification Cross Index—Including Discontinued Zirconium Electrodes**

| Filler Metal       |              |              |       |             | Base Metal            |                                 |
|--------------------|--------------|--------------|-------|-------------|-----------------------|---------------------------------|
| AWS Classification |              |              |       |             | ASTM/ASME Base Number |                                 |
| 2005               | 1990         | 1979         | 1976  | UNS Numbers | UNS Number            | Grade Designations <sup>a</sup> |
| Discontinued       | Discontinued | Discontinued | ERZr1 |             |                       |                                 |
| ERZr2              | ERZr2        | ERZr2        | ERZr2 | R60702      | R60702                | Unalloyed Zr                    |
| ERZr3              | ERZr3        | ERZr3        | ERZr3 | R60704      | R60704                | Zr-Fe-Sn-Cr                     |
| ERZr4              | ERZr4        | ERZr4        | —     | R60705      | R60705                | Zr-2.5%Nb                       |

Note:

a. Reference: ASTM B 493, B 523, B 551, and B 653.

## A2.4 Request for Filler Metal Classification

**A2.4.1** When a filler metal cannot be classified according to some existing classification, the manufacturer may request that a classification be established for that filler metal. They may do this by following the procedure given here.

**A2.4.2** A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need.

In particular, the request needs to include:

(1) All classification requirements as given for existing classifications, such as all chemical composition ranges.

(2) Information on “Description and Intended Use,” which parallels that for existing classifications, for that section of Annex A.

A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requestor for further information.

**A2.4.3** The request should be sent to the Secretary of the A5 Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

(1) Assign an identifying number to the request. This number shall include the date the request was received.

(2) Confirm receipt of the request and give the identification number to the person who made the request.

(3) Send a copy of the request to the Chair of the A5 Committee on Filler Metals and Allied Materials and the Chair of the particular Subcommittee involved.

(4) File the original request.

(5) Add the request to the log of outstanding requests.

**A2.4.4** All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a “timely manner” and the Secretary shall report these to the Chair of the A5 Committee on Filler Metals and Allied Materials, for action.

**A2.4.5** The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be

at the option of the American Welding Society, as deemed appropriate.

## A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01, *Filler Metal Procurement Guidelines*, as the Specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, needs to be clearly stated in the purchase order, according to the provisions of AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of the *Filler Metal Procurement Guidelines*. Testing in accordance with any other Schedule in that Table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

## A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product or the classification on the product itself, constitutes the supplier’s (manufacturer’s) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. “Certification” is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of “representative material” cited above, and the “Manufacturer’s Quality Assurance Program” in AWS A5.01, *Filler Metal Procurement Guidelines*.

## A5. Ventilation During Welding

**A5.1** Five major factors govern the quantity of fumes to which welders and welding operators are exposed during welding:

(1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling).

(2) Number of welders and welding operators working in that space.

(3) Rate of evolution of fumes, gases, or dust, according to the materials and processes used.

(4) The proximity of the welders or welding operators to the fumes as the fumes issue from the welding zone, and to the gases and dusts in the space in which they are working.

(5) The ventilation provided to the space in which the welding is done.

**A5.2** American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section of that document, entitled "Ventilation."

## A6. Welding Considerations

**A6.1** Zirconium and zirconium alloys can be welded by gas tungsten arc, gas metal arc, plasma arc, and electron beam welding processes. Zirconium is a reactive metal and is sensitive to embrittlement by oxygen, nitrogen and hydrogen at temperatures above 1100°F [590°C]. Consequently, the metal should be protected from atmospheric contamination. This can be provided by shielding the metal with high purity inert gas, or by placing in an inert gas chamber or a vacuum of 10 to the minus 4 torr [0.013 Pa] or lower. During arc welding, the zirconium should be shielded from the atmosphere until it is cooled below about 800°F [430°C]. Adequate protection by auxiliary inert gas shielding should be provided when welding in air, and for critical applications the welding should be done in a gas tight chamber thoroughly purged of air and filled with high purity inert gas.

The zirconium metal should be free of heavy oxide and chemically clean prior to welding, as contamination from oxide, water, grease, and dirt will also cause embrittlement.

Zirconium welding rods must be chemically clean and free of heavy oxide, absorbed moisture, grease, and dirt. The welding rod should be kept in the inert gas during welding and the oxide at the tip, formed upon cooling, must be removed before reusing the rod.

Zirconium can be successfully fusion welded to titanium, tantalum, niobium (columbium), and vanadium although the weld metal will be stronger and less ductile than the base metals. Zirconium cannot be welded to other common structural alloys of copper, iron, nickel, and aluminum as brittle zirconium intermetallic alloys are formed which produce extremely brittle welds.

## A7. Description and Intended Use of Electrodes and Rods

**A7.1** The ERZr2 classification is a "commercially pure" zirconium. It produces weld metal having good strength and ductility. The tensile strength should be at least 55 ksi [380 MPa]. These electrodes and rods are intended to be used for welding the UNS R60702 zirconium alloy.

**A7.2** The ERZr3 classification contains tin as an alloying element. Tin increases the strength of the weld metal, yet allows it to retain good ductility. The strength should be at least 60 ksi [410 MPa]. These electrodes and rods are intended only for welding UNS R60704 zirconium alloy. Weld metal from ERZr3 filler metal may not resist corrosion as well as that from ERZr2 filler metal.

**A7.3** The ERZr4 classification contains niobium (columbium) as an alloying element. It produces weld metal of good ductility with a tensile strength of at least 80 ksi [550 MPa]. These electrodes and rods are used only to weld UNS R60705 zirconium alloy. Weld metal from ERZr4 filler metal may not resist corrosion as well as that from ERZr2 filler metal. All welds utilizing ERZr4 filler metal should be post weld heat treated to reduce the susceptibility for delayed hydride cracking.

## A8. Special Tests

It is recognized that for certain applications, supplementary tests may be required. In such cases, additional tests to determine specific properties, such as corrosion-resistance, scale-resistance, or strength at elevated temperatures may be required. AWS A5.01, *Filler Metal Procurement Guidelines* provides a means by which such tests can be incorporated into the purchase order. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

**A8.1 Corrosion Tests.** Although welds made with electrodes and rods in this specification are commonly used in corrosion applications, tests for those properties are not included in the specification. When required for a particular application, tests can be conducted on specimens taken from either a weld pad or a welded joint. Specimens from a joint are suitable for qualifying the welding procedure (for a specific application involving corrosion or oxidation resistance) but not for qualifying the electrode. Tests on specimens from a joint have the disadvantage of being a combined test of the properties of the weld metal, the heat-affected zone (HAZ), and the unaffected base metal. With them, it is more difficult to obtain reproducible data (when a difference exists in the properties of the metal in the various parts of the specimen).

Specimens taken from a joint have the advantage of being able to duplicate the joint design and the welding sequence planned for fabrication.

**A8.1.1** Specimens for testing the corrosion resistance of the weld metal alone are prepared by following a procedure as agreed upon by purchaser and supplier. The pad size should be at least  $\frac{3}{4}$  in [19 mm] in height,  $2\frac{1}{2}$  in [65 mm] in width, and  $1 + \frac{5}{8}n$  (in) [ $25 + 16n$  {mm}] in length, where  $n$  represents the number of specimens required from the pad. Specimens measuring  $\frac{1}{2} \times 2 \times \frac{1}{4}$  in [ $13 \times 50 \times 6.4$  mm] are machined from the top of the pad in a manner such that the 2 in [50 mm] dimension of the specimen is parallel with the  $2\frac{1}{2}$  in [65 mm] dimension of the pad and the  $\frac{1}{2}$  in [13 mm] dimension is parallel with the length of the pad.

**A8.1.2** The heat treatment, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedures should correspond to those of ASTM G 4, *Standard Practice for Conducting Plant Corrosion Tests*, or ASTM G 31, *Recommended Practice for Laboratory Immersion Corrosion Testing of Metals*, as the case may be.

## A9. Discontinued Classifications

One classification has been discontinued from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The classification that has been discontinued is listed in Table A1, along with the year in which it was last included in the specification.

## A10. General Safety Considerations

*Note: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addresses herein. Some safety and health information can be found in Annex Section A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1 Safety in Welding, Cutting, and Allied Processes<sup>7</sup>, and applicable federal and state regulations.*

7. This standard can be obtained from 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](http://www.global.ihs.com).

**A10.1 Safety and Health Fact Sheets.** The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at <http://www.aws.org>. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

### A10.2 AWS Safety and Health Fact Sheets Index (SHF)<sup>8</sup>

| No. | Title                                                            |
|-----|------------------------------------------------------------------|
| 1   | <i>Fumes and Gases</i>                                           |
| 2   | <i>Radiation</i>                                                 |
| 3   | <i>Noise</i>                                                     |
| 4   | <i>Chromium and Nickel in Welding Fume</i>                       |
| 5   | <i>Electric Hazards</i>                                          |
| 6   | <i>Fire and Explosion Prevention</i>                             |
| 7   | <i>Burn Protection</i>                                           |
| 8   | <i>Mechanical Hazards</i>                                        |
| 9   | <i>Tripping and Falling</i>                                      |
| 10  | <i>Falling Objects</i>                                           |
| 11  | <i>Confined Space</i>                                            |
| 12  | <i>Contact Lens Wear</i>                                         |
| 13  | <i>Ergonomics in the Welding Environment</i>                     |
| 14  | <i>Graphic Symbols for Precautionary Labels</i>                  |
| 15  | <i>Style Guidelines for Safety and Health Documents</i>          |
| 16  | <i>Pacemakers and Welding</i>                                    |
| 17  | <i>Electric and Magnetic Fields (EMF)</i>                        |
| 18  | <i>Lockout/Tagout</i>                                            |
| 19  | <i>Laser Welding and Cutting Safety</i>                          |
| 20  | <i>Thermal Spraying Safety</i>                                   |
| 21  | <i>Resistance Spot Welding</i>                                   |
| 22  | <i>Cadmium Exposure from Welding &amp; Allied Processes</i>      |
| 23  | <i>California Proposition 65</i>                                 |
| 24  | <i>Fluxes for Arc Welding and Brazing: Safe Handling and Use</i> |
| 25  | <i>Metal Fume Fever</i>                                          |

8. AWS standards can be obtained from 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](http://www.global.ihs.com).

## Annex B

# Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A5.24/A5.24M:2005, *Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*, but is included for informational purposes only.)

### B1. 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.

### B2. 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 type-written and should also be in the format used here.

**B2.1 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.

**B2.2 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.

**B2.3 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.

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

### B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the chairman 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.

#### **B4. Publication of Interpretations**

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

#### **B5. Telephone Inquiries**

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The 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.

#### **B6. 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.

**AWS Filler Metal Specifications by Material and Welding Process**

|                           | OFW   | SMAW  | GTAW<br>GMAW<br>PAW | FCAW  | SAW   | ESW   | EGW   | Brazing     |
|---------------------------|-------|-------|---------------------|-------|-------|-------|-------|-------------|
| Carbon Steel              | A5.2  | A5.1  | A5.18               | A5.20 | A5.17 | A5.25 | A5.26 | A5.8, A5.31 |
| Low-Alloy Steel           | A5.2  | A5.5  | A5.28               | A5.29 | A5.23 | A5.25 | A5.26 | A5.8, A5.31 |
| Stainless Steel           |       | A5.4  | A5.9, A5.22         | A5.22 | A5.9  | A5.9  | A5.9  | A5.8, A5.31 |
| Cast Iron                 | A5.15 | A5.15 | A5.15               | A5.15 |       |       |       | A5.8, A5.31 |
| Nickel Alloys             |       | A5.11 | A5.14               |       | A5.14 |       |       | A5.8, A5.31 |
| Aluminum Alloys           |       | A5.3  | A5.10               |       |       |       |       | A5.8, A5.31 |
| Copper Alloys             |       | A5.6  | A5.7                |       |       |       |       | A5.8, A5.31 |
| Titanium Alloys           |       |       | A5.16               |       |       |       |       | A5.8, A5.31 |
| Zirconium Alloys          |       |       | A5.24               |       |       |       |       | A5.8, A5.31 |
| Magnesium Alloys          |       |       | A5.19               |       |       |       |       | A5.8, A5.31 |
| Tungsten Electrodes       |       |       | A5.12               |       |       |       |       |             |
| Brazing Alloys and Fluxes |       |       |                     |       |       |       |       | A5.8, A5.31 |
| Surfacing Alloys          | A5.21 | A5.13 | A5.21               | A5.21 | A5.21 |       |       |             |
| Consumable Inserts        |       |       | A5.30               |       |       |       |       |             |
| Shielding Gases           |       |       | A5.32               | A5.32 |       |       | A5.32 |             |

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## AWS Filler Metal Specifications and Related Documents

| Designation  | Title                                                                                                                                                                     |
|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| FMC          | <i>Filler Metal Comparison Charts</i>                                                                                                                                     |
| IFS          | <i>International Index of Welding Filler Metal Classifications</i>                                                                                                        |
| UGFM         | <i>User's Guide to Filler Metals</i>                                                                                                                                      |
| A4.2M/A4.2   | <i>Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal</i> |
| A4.3         | <i>Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding</i>              |
| A4.4M        | <i>Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings</i>                                                   |
| A5.01        | <i>Filler Metal Procurement Guidelines</i>                                                                                                                                |
| A5.1/A5.1M   | <i>Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding</i>                                                                                           |
| A5.2         | <i>Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding</i>                                                                                          |
| A5.3/A5.3M   | <i>Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding</i>                                                                            |
| A5.4         | <i>Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding</i>                                                                                        |
| A5.5         | <i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>                                                                                        |
| A5.6         | <i>Specification for Covered Copper and Copper Alloy Arc Welding Electrodes</i>                                                                                           |
| A5.7         | <i>Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes</i>                                                                                         |
| A5.8/A5.8M   | <i>Specification for Filler Metals for Brazing and Braze Welding</i>                                                                                                      |
| A5.9         | <i>Specification for Bare Stainless Steel Welding Electrodes and Rods</i>                                                                                                 |
| A5.10/A5.10M | <i>Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods</i>                                                                                     |
| A5.11/A5.11M | <i>Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding</i>                                                                        |
| A5.12/A5.12M | <i>Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting</i>                                                                               |
| A5.13        | <i>Specification for Surfacing Electrodes for Shielded Metal Arc Welding</i>                                                                                              |
| A5.14/A5.14M | <i>Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods</i>                                                                                         |
| A5.15        | <i>Specification for Welding Electrodes and Rods for Cast Iron</i>                                                                                                        |
| A5.16/A5.16M | <i>Specification for Titanium and Titanium Alloy Welding Electrodes and Rods</i>                                                                                          |
| A5.17/A5.17M | <i>Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding</i>                                                                                     |
| A5.18/A5.18M | <i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>                                                                                    |
| A5.19        | <i>Specification for Magnesium Alloy Welding Electrodes and Rods</i>                                                                                                      |
| A5.20        | <i>Specification for Carbon Steel Electrodes for Flux Cored Arc Welding</i>                                                                                               |
| A5.21        | <i>Specification for Bare Electrodes and Rods for Surfacing</i>                                                                                                           |
| A5.22        | <i>Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding</i>                           |
| A5.23/A5.23M | <i>Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding</i>                                                                                  |
| A5.24/A5.24M | <i>Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods</i>                                                                                        |
| A5.25/A5.25M | <i>Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding</i>                                                                         |
| A5.26/A5.26M | <i>Specification for Carbon and Low-Alloy Steel Electrodes for Electrode Gas Welding</i>                                                                                  |
| A5.28        | <i>Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding</i>                                                                                 |
| A5.29        | <i>Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding</i>                                                                                            |
| A5.30        | <i>Specification for Consumable Inserts</i>                                                                                                                               |
| A5.31        | <i>Specification for Fluxes for Brazing and Braze Welding</i>                                                                                                             |
| A5.32/A5.32M | <i>Specification for Welding Shielding Gases</i>                                                                                                                          |

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