

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



American Welding Society

Keywords— Zirconium alloy wire, zirconium welding electrodes, zirconium welding rods, gas metal arc welding, gas tungsten arc welding, plasma arc welding

ANSI/AWS A5.24-90
An American National Standard

Approved by
American National Standards Institute
March 14, 1990

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

Supersedes
AWS A5.24-79

Prepared by
AWS Committee on Filler Metal

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification provides the composition of three classifications of zirconium welding electrodes and rods, along with standard sizes and package forms. The appendix provides some useful information concerning the classification system, acceptance, certification, ventilation during welding, and the intended use of the filler metals.



American Welding Society

550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

Statement on Use of AWS Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute. When AWS standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

International Standard Book Number: 0-87171-323-3

American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

© 1990 by American Welding Society. All rights reserved
Printed in the United States of America

Note: The primary purpose of AWS is to serve and benefit its members. To this end, AWS provides a forum for the exchange, consideration, and discussion of ideas and proposals that are relevant to the welding industry and the consensus of which forms the basis for these standards. By providing such a forum, AWS does not assume any duties to which a user of these standards may be required to adhere. By publishing this standard, the American Welding Society does not insure anyone using the information it contains against any liability arising from that use. Publication of a standard by the American Welding Society does not carry with it any right to make, use, or sell any patented items. Users of the information in this standard should make an independent investigation of the validity of that information for their particular use and the patent status of any item referred to herein.

This standard is subject to revision at any time by the AWS Filler Metal Committee. It must be reviewed every five years and if not revised, it must be either reapproved or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful considerations by the AWS Filler Metal Committee and the author of the comments will be informed of the committee's response to the comments. Guests are invited to attend all meetings of the AWS Filler Metal Committee to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

Personnel

AWS Committee on Filler Metal (As of April, 1989)

<i>W. L. Wilcox, Chairman</i>	Consultant
<i>D. J. Kotecki, 1st Vice Chairman</i>	Teledyne McKay
<i>D. F. Betz, 2nd Vice Chairman</i>	Crane Midwest
<i>W. A. Dierschow, Secretary</i>	American Welding Society
<i>Z. Al-Hillal</i>	Liquid Carbonic
<i>D. R. Amos</i>	Westinghouse Turbine Plant
<i>B. E. Anderson</i>	Alcotec
<i>K. E. Banks</i>	Teledyne McKay
<i>J. B. Bolton</i>	Kennametal, Incorporated
<i>R. S. Brown</i>	Carpenter Technology Corporation
<i>J. Caprarola, Jr.</i>	Alloy Rods
<i>L. J. Christensen*</i>	Consultant
<i>R. J. Christoffel</i>	Consultant
<i>D. A. DelSignore</i>	Westinghouse Electric Company
<i>P. B. Dickerson*</i>	Consultant
<i>H. W. Ebert</i>	Exxon Research and Engineering Company
<i>D. A. Fink</i>	The Lincoln Electric Company
<i>J. Gonzalez</i>	The Lincoln Electric Company
<i>R. L. Harris*</i>	R. L. Harris Associates
<i>G. Hallstrom, Jr.</i>	USNRC-R11
<i>D. C. Helton</i>	Consultant
<i>W. S. Howes</i>	National Electrical Manufacturers Association
<i>J. P. Hunt</i>	Inco Alloys International
<i>P. A. Kammer*</i>	Eutectic Corporation
<i>R. B. Kadiyala</i>	Techalloy Maryland, Incorporated
<i>G. A. Kurisky</i>	Maryland Specialty Wire
<i>R. A. LaFave</i>	Elliott Company
<i>N. E. Larson</i>	Union Carbide Corporation Linde Division
<i>A. S. Laurenson</i>	Consultant
<i>G. H. MacShane</i>	Stoody Corporation
<i>L. M. Malik*</i>	Arctec Canada Limited
<i>W. F. McLaughlin</i>	Chrysler Corporation
<i>M. T. Merlo</i>	Tri-Mark
<i>G. E. Metzger</i>	WRDC/MLLS
<i>J. W. Mortimer</i>	Consultant
<i>L. W. Mott</i>	Hobart Brothers Company
<i>C. L. Null</i>	Department of Navy
<i>Y. Ogata*</i>	Kobe Steel America Incorporated
<i>J. Payne</i>	Schneider Services International
<i>R. L. Peaslee</i>	Wall Colmonoy Corporation
<i>E. W. Pickering</i>	Combustion Engineering, Incorporated

*Advisor

<i>L. F. Roberts</i>	Canadian Welding Bureau
<i>S. D. Reynolds, Jr.*</i>	Westinghouse GTSD.
<i>D. Rozet</i>	Consultant
<i>H. S. Sayre*</i>	Consultant
<i>P. K. Salvesen</i>	American Bureau of Shipping
<i>O. W. Seth</i>	Chicago Bridge and Iron Company
<i>R. W. Straiton</i>	Bechtel Group
<i>R. D. Sutton</i>	L-Tec Welding and Cutting
<i>R. A. Swain</i>	Welders Supply
<i>J. W. Tackett</i>	Hayes International, Incorporated
<i>R. D. Thomas, Jr.</i>	R. D. Thomas and Company
<i>R. Timmerman*</i>	Conarco, S.A.
<i>R. T. Webster</i>	Teledyne Wah Chang
<i>A. E. Wiehe*</i>	Consultant
<i>W. A. Wiehe</i>	Arcos Division, Hoskins Manufacturing Company
<i>F. J. Winsor</i>	Consultant
<i>K. G. Wold</i>	Welding Consultants USA
<i>T. J. Wonder</i>	VSE Corporation

AWS Subcommittee on Titanium and Zirconium Filler Metal
(As of April, 1989)

<i>R. T. Webster, Chairman</i>	Teledyne Wah Chang
<i>F. S. Babish</i>	Sandvik, Incorporated
<i>W. A. Dierschow, Secretary</i>	American Welding Society
<i>R. P. Barb</i>	General Electric Company
<i>C. A. Cardarelli</i>	Reactive Corporation
<i>R. DeNale</i>	David Taylor Naval Ship R&D Center
<i>J. Meyer</i>	Nooter Corporation
<i>C. I. Monaco</i>	Western Zirconium
<i>H. Nagler</i>	Rohr Industries, Incorporated
<i>H. S. Sayre*</i>	Consultant
<i>A. P. Seidler</i>	RMI Company
<i>A. W. Sindel</i>	C-E Natco
<i>J. J. Vagi</i>	Consultant

*Advisor

Foreword

(This Foreword is not a part of ANSI/AWS A5.24-90, *Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods*, but is supplied for information only.)

ANSI/AWS A5.24-90 *Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods* is the second revision of the document issued initially in 1976. With exception of the deletion of the ERZr1 classification in 1979 and the check analysis tolerances in this revision, 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 the appendix.

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*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS Filler Metal Committee, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

Table of Contents

	Page No.
<i>Personnel</i>	iii
<i>Foreword</i>	v
<i>List of Tables</i>	vii
<i>List of Figures</i>	vii
1. Scope	1
<i>Part A—General Requirements</i>	1
2. Classification	1
3. Acceptance	1
4. Certification	1
5. Units of Measure and Rounding-Off Procedure	1
<i>Part B—Test, Procedures, and Requirements</i>	2
6. Summary of Tests	2
7. Retest	2
8. Chemical Analysis	2
<i>Part C—Manufacture, Identification, and Packaging</i>	2
9. Method of Manufacture	2
10. Standard Sizes	2
11. Finish and Uniformity	3
12. Standard Package Forms	3
13. Winding Requirements	3
14. Filler Metal Identification	3
15. Packaging	5
16. Marking of Packages	5
<i>Appendix: Guide to the AWS Specification for Zirconium and Zirconium Alloy Bare Welding</i>	
<i>Electrodes and Rods</i>	7
A1. Introduction	7
A2. Method Classification	7
A3. Acceptance	7
A4. Certification	7
A5. Ventilation During Welding	8
A6. Welding Considerations	8
A7. Description and Intended Use of Electrodes and Rods	8
A8. Special Tests	8
<i>Filler Metal Related Documents</i>	9

List of Tables

Table	Page No.
1 Chemical Composition Requirements for Zirconium and Zirconium Electrodes and Rods.....	2
2 Standard Sizes for Filler Metal in Straight Lengths and Coils With or Without Support	3
3 Standard Sizes for Filler Metal on Spools.....	4

List of Figures

Figure	Page No.
1 Dimensions of Standard 4 in. (100 mm) Spools	4
2 Dimensions of Standard 12 in. (300 mm) Spools for 10 and 25 lb (4.5 and 11. kg) of Filler Metal	4

Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods

1. Scope

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

Part A *General Requirements*

2. Classification

2.1 The welding materials covered by this specification are classified according to the chemical composition of the filler metal as specified in Table 1.

2.2 Material classified under one classification shall not be classified under any other classification of this specification.

2.3 The materials classified under this specification are intended for plasma arc, gas metal arc, and gas tungsten arc welding, but that is not to prohibit their use with any other process for which they are found suitable.

3. Acceptance

Acceptance¹ of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.²

1. See A3 (in the Appendix) for further information concerning acceptance, testing of the material shipped, and ANSI/A5.01, *Filler Metal Procurement Guidelines*.

2. AWS standards can be obtained from the American Welding Society 550 N.W. LeJeune Road, P. O. Box 351040, Miami, Florida 33135.

4. 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.³

5. Units of Measure and Rounding-off Procedure

5.1 U.S. Customary Units are the standard units of measure in this specification. The SI Units are given as equivalent values to the U.S. Customary Units. The standard sizes and dimensions in the two systems are not identical, and for this reason conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable conversions, encompassing standard sizes of both can be made, however, if appropriate tolerances are applied in each case.

5.2 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 limiting values in accordance with the rounding-off method given in ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*.

3. See A4 (in the Appendix) for further information concerning Certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements for Zirconium and
Zirconium Electrodes and Rods

AWS Classi- fication	Chemical Composition, Wt Percent ^a									
	UNS Number ^b	Zirconium + Hafnium	Hafnium	Iron + Chromium	Tin	Oxygen	Hydrogen	Nitrogen	Carbon	Colum- bium
ERZr2	R60702	99.01 min	4.5	0.20	—	0.016	0.005	0.025	0.05	—
ERZr3	R60704	97.5 min	4.5	0.20 to 0.40	1.00 to 2.00	0.016	0.005	0.025	0.05	—
ERZr4	R60705	95.5 min	4.5	0.20	—	0.016	0.005	0.025	0.05	2.0 to 3.0

Notes:

a. Single values are maximum, except as noted.

b. ASTM/SAE Unified Numbering System for Metals and Alloys. Document may be obtained from SAE, Inc. 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001.

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.

Part B

Tests, Procedures, and Requirements

6. Summary of Tests

Chemical analysis of the filler metal (or, as an alternative for part of the analysis, the stock from which the filler metal is made—see note c to Table 1) is the only test required for classification of a product under this specification.

7. Retest

If the result of any test fails to meet its requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Samples for retest may be taken from the original test sample or from one or two new samples. Retest need be only for those specific elements that failed to meet the test requirement.

8. Chemical Analysis

8.1 A sample of the filler metal, or the rod stock from which it was made, shall be prepared for chemical analysis.

8.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM Method

E146, *Chemical Analysis of Zirconium and Zirconium Alloys*.⁴

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

Part C

Manufacture, Identification, and Packaging

9. 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.

10. Standard Sizes

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

4. ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Table 2
Standard Sizes^a for Filler Metal in
Straight Lengths and Coils With or Without Support

Standard Package Form	Diameter		Tolerance	
	in.	mm	in.	mm
Straight lengths, ^b coils with support, coils without support	1/16 (0.062)	1.6		
	5/64 (0.078)	2.0		
	3/32 (0.094)	2.4		
	1/8 (0.125)	3.2	± 0.002	± 0.05
	5/32 (0.156)	4.0		
	3/16 (0.187)	4.8		
Spools	0.020	0.5		
	0.030	0.8	+ 0.001	+ 0.03
	0.035	0.9	- 0.002	- 0.05
	0.045	1.2		
	1/16 (0.062)	1.6	± 0.002	± 0.05

Notes:

a. Dimensions, sizes, tolerances, and package forms other than these shall be as agreed to by the purchaser and the supplier.

b. Length shall be 36 in. ± 1/4 in. (915 mm ± 6 mm).

11. Finish and Uniformity

11.1 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.

11.2 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 the uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

12. Standard Package Forms

12.1 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 to between purchaser and supplier.

12.2 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.

12.3 Spools (Figures 1 and 2) 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.

13. Winding Requirements

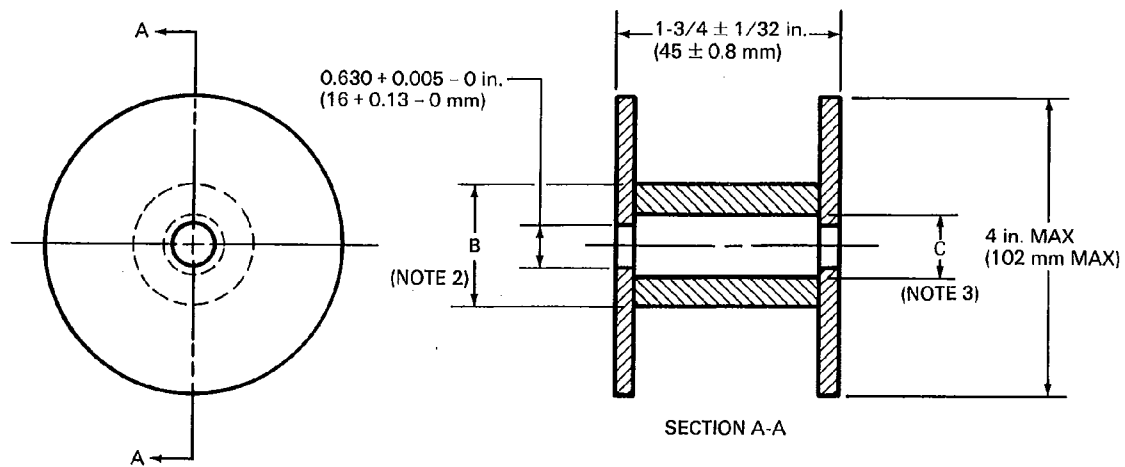
13.1 The filler metal shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end welding is to begin with) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

13.2 When required, level winding shall be used.

13.3 The cast and helix of the electrode in coils and in spools shall be such that the filler metal will feed in an uninterrupted manner in automatic and semiautomatic equipment.

14. Filler Metal Identification

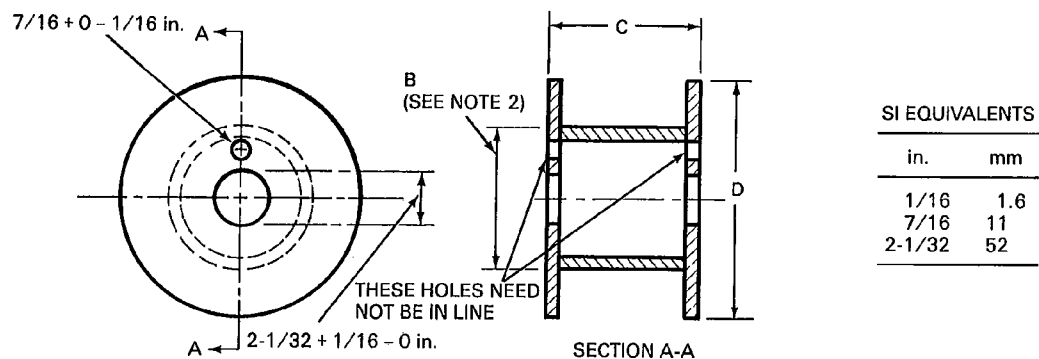
14.1 The product information and the precautionary information required in section 16, Marking of Packages, shall appear also on each coil and spool.



Notes:

1. All dimensions are in inches (millimeters).
2. Dimension B, outside diameter of the barrel, shall be such as to permit proper feeding of the filler metals.
3. Dimension C, 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.

Figure 1 — Dimensions of Standard 4 in. (100 mm) Spools



Note: Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

Dimensions					
Spool Size		C		D, Maximum	
in.	mm	in.	mm	in.	mm
12	300	4 ± 1/16	100 ± 2	12	305

Figure 2 — Dimensions of Standard 12 in. (300 mm) Spools for 10 and 25 lb (4.5 and 11 kg) of Filler Metal

Table 3
Standard Package Dimensions and Weights

Filler Metal Size ^a		Net Weight of Package ^{a,b}		Width ^c		Diameter			
						Inside ^d		Outside	
in.	mm	lb.	kg	in.	mm	in.	mm	in.	mm
<u>Straight Lengths</u>									
1/16 through 3/16	1.6 through 4.8	{ 10 50	4.5 23	—	—	—	—	—	—
<u>Coils With Support and Coils Without Support</u>									
1/16 through 3/16	1.6 through 4.8	25	11	{ 2-1/2 or 4-5/8	{ 65 or 120	12 ± 1/8	305 ± 3	13-5/8 15-1/8	345 400
		50 60	23 27	4-5/8	120			17 17-1/2	420 430
<u>Spools</u>									
0.020 through 1/16	0.5 through 1.6	{ 1 5 15	0.5 2.2 6.8	See Figure 1 See Figure 2 See Figure 2		— — —	— — —	See Figure 1 See Figure 2 See Figure 2	

Notes:

- Sizes, dimensions, and weights other than these shall be as agreed to by the purchaser and the supplier.
- Actual net weight of the filler metal in each package shall be within 10 percent of the standard net weight shown.
- Width of coils and spools.
- Inside diameter of the liner for coils with support, and of the coil itself, for coils without support.

14.2 Coils without support shall have a tag containing this information securely attached to the inside end of the coil.

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

14.4 Spools shall have the information securely affixed in a prominent location on the outside of one flange of the spool.

15. Packaging

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

16. Marking of Packages

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

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

16.2 The following precautionary information (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.

WARNING:

Protect yourself and others.

Read and understand this information.

FUMES AND GASES can be dangerous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; *OSHA Safety and Health Standards*, 29 CFR 1910, available from U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Appendix

Guide to the AWS Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods

(This Appendix is not a part of ANSI/AWS A5.24-90, *Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods*, but is included for information purposes only.)

A1. Introduction

A1.1 The specification is intended to provide both the supplier and the purchaser of zirconium and zirconium alloy bare welding electrodes and rods with a means of product control and a basis of acceptance through mutually acceptable, sound, standard requirements.

A1.2 This guide has been prepared as an aid to prospective users of zirconium and zirconium alloy filler metals included in the specification to determine the classification best suited for a particular application, with due consideration to the particular requirements for that application.

the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/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 must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A2. Method of Classification

A2.1 The system of classification is similar to that used in other filler metal specifications. The letter "E" at the beginning of each designation indicates a welding electrode, and the letter "R" indicates a welding rod. Since these filler metals are used as welding electrodes in gas metal arc welding and as welding rods in gas tungsten arc welding, both letters are used.

The letters "Zr" indicate that the filler metals have a zirconium base. The digits and letters that follow provide a means for identifying the nominal composition of the filler metal.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the Specification states. Any testing a purchaser requires of

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 ANSI/A5.01, *Filler Metal Procurement Guidelines*.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere 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 process involved
- (4) The proximity of the welders or welding operators to the fumes as they 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 and Cutting* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is directed particularly to the section of that document on "Health Protection and 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 in air, in a chamber, or by a vacuum of 10^{-4} torr or lower. During arc welding, the zirconium must be shielded from the atmosphere until it is cooled below about 1100°F (593°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, columbium (niobium), and vanadium although the weld metal will be stronger and less ductile than the base metals. Zirconium should not be fusion 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 55 000 psi (379 MPa). These electrodes and rods can be used to weld all of the zirconium alloys.

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 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.

A8. Special Tests

It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as (corrosion resistance, scaling resistance, or strength at elevated temperatures or cryogenic temperatures) may be required. ANSI/AWS A5.01, *Filler Metal Procurement Guidelines* contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed upon between supplier and purchaser.

AWS Filler Metal Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal
A4.3	Standard Procedures for Determination of Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Covered Carbon Steel Arc Welding Electrodes
A5.2	Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding
A5.3	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Corrosion-Resisting Chromium Nickel Steel Welding Electrodes
A5.5	Specification for Low Alloy Steel Covered Arc Welding Electrodes
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing
A5.9	Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods
A5.10	Specification for Aluminum and Aluminum Alloy Bare Welding Rods and Electrodes
A5.11	Specification for Nickel and Nickel Alloy Covered Welding Electrodes
A5.12	Specification for Tungsten Arc Welding Electrodes
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
A5.14	Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods
A5.15	Specification for Welding Electrodes and Rods for Cast Iron
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
A5.17	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Rods and Bare Electrodes
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes
A5.23	Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25	Specification for Consumables Used for Electroslag Welding of Carbon and High Strength Low Alloy Steels

AWS Designation	Title
A5.26	Specification for Consumables Used for Electrode Gas Welding of Carbon and High Strength Low Alloy Steels
A5.27	Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding
A5.28	Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding
A5.29	Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts

For additional information, contact the Order Department, The American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135, Phone: (305) 443-9353.