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An American National Standard

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



American Welding Society

Keywords— Titanium, titanium alloy welding electrodes, titanium welding rods, filler metal specifications

ANSI/AWS A5.16-90
An American National Standard

Approved by
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Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

Supersedes
AWS A5.16-70

Prepared by
AWS Committee on Filler Metal

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification is a revision of the titanium welding electrode document last revised in 1970. The compositions specified for each classification represent the latest state-of-the-art. A new numerical designation system is introduced to make the system more compatible with commercial practice. The specification contains testing procedures, standard sizes and forms, and identification and marking practices.

The Appendix has been totally reorganized. Handbook data have been deleted. Each of the 13 classifications is described briefly with general information concerning the application of filler metal of each classification.



American Welding Society

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Foreword

(This Foreword is not a part of ANSI/AWS A5.16-90, *Specification for Titanium and Titanium Alloy Welding Electrodes and Rods*, but is included for information purposes only.)

The first specification for titanium electrodes and welding rods was developed more than 25 years ago by a joint committee of the American Welding Society and the American Society for Testing and Materials. It was published initially in 1961.

The 1970 Revision was the first version of this specification to be published entirely by AWS. Three years later, it was recognized by the American National Standards Institute.

AWS A5.16-61T Tentative Specification for Titanium
ASTM B362-61T Alloy Bare Welding Rods and Electrodes

AWS A5.16-70 Specification for Titanium and Titanium
ANSI W3.16-1973 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—Tests, Procedures, and Requirements</i>	1
6. Summary of Tests	1
7. Retest	3
8. Chemical Analysis	3
<i>Part C—Manufacture, Identification, and Packaging</i>	3
9. Method of Manufacture	3
10. Standard Sizes	3
11. Finish and Uniformity	3
12. Standard Package Forms	3
13. Winding Requirements	3
14. Filler Metal Identification	6
15. Packaging	6
16. Marking of Packages	6
<i>Appendix: Guide to AWS Specification for Titanium and Titanium Alloy Welding</i>	
<i>Electrodes and Rods</i>	7
A1. Introduction	7
A2. Classification System	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	9
A8. Special Tests	10
<i>Filler Metal Related Documents</i>	11

List of Tables

Table	Page No.
1 Chemical Composition Requirements for Titanium and Titanium Alloy Electrodes and Rods	2
2 Standard Sizes	4
3 Standard Package Dimensions and Weights	4
A1 Specification Cross Index	8

List of Figures

Figure	Page No.
1 Dimensions of 4 in. (100 mm) Spools	5
2 Dimensions of 8 and 12 in. (200 and 300 mm) Spools	5

Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

1. Scope

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

Part A *General Requirements*

2. Classification

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

2.2 Materials classified under one classification shall not be classified under any other classification of this specification, except that ERTi-1 may be classified also as ERTi-2.

2.3 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 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 Section A3 (in the Appendix) for further information concerning acceptance, testing of the material shipped, and 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 the limiting value in accordance with the rounding-off method given in ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*.

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

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

Table 1
Chemical Composition Requirements For Titanium and Titanium Alloy Electrodes and Rods

AWS Classification		Weight Percent ^{a,b,c,d}										Other	
1990	1970	UNS Number ^e	Carbon	Oxygen	Hydrogen	Nitrogen	Aluminum	Vanadium	Tin	Iron	Element	Amount	Amount
ERTi-1	ERTi-1	R50100	0.03	0.10	0.005	0.015	...	...	...	0.10	...	...	...
ERTi-2	ERTi-2	R50120	0.03	0.10	0.008	0.020	...	...	...	0.20	...	...	...
ERTi-3	ERTi-3	R50125	0.03	0.10-0.15	0.008	0.020	...	...	...	0.20	...	...	...
ERTi-4	ERTi-4	R50130	0.03	0.15-0.25	0.008	0.020	...	...	...	0.30	...	...	...
ERTi-5	ERTi-6Al-4V	R56400	0.05	0.18	0.015	0.030	5.5-6.7	3.5-4.5	...	0.30	Yttrium	0.005	0.005
ERTi-5ELI	ERTi-6Al-4V-1	R56402	0.03	0.10	0.005	0.012	5.5-6.5	3.5-4.5	...	0.15	Yttrium	0.005	0.005
ERTi-6	ERTi-5Al-2.5Sn	R54522	0.08	0.18	0.015	0.050	4.5-5.8	...	2.0-3.0	0.50	Yttrium	0.005	0.005
ERTi-6ELI	ERTi-5Al-2.5Sn-1	R54523	0.03	0.10	0.005	0.012	4.5-5.8	...	2.0-3.0	0.20	Yttrium	0.005	0.005
ERTi-7	ERTi-0.2Pd	R52401	0.03	0.10	0.008	0.020	...	...	...	0.20	Palladium	0.12/0.25	0.12/0.25
ERTi-9	ERTi-3Al-2.5V	R56320	0.03	0.12	0.008	0.020	2.5-3.5	2.0-3.0	...	0.25	Yttrium	0.005	0.005
ERTi-9ELI	ERTi-3Al-2.5V-1	R56321	0.03	0.10	0.005	0.012	2.5-3.5	2.0-3.0	...	0.20	Yttrium	0.005	0.005
ERTi-12		R53400	0.03	0.25	0.008	0.020	...	...	...	0.30	Molybdenum	0.2/0.4	0.2/0.4
ERTi-15	ERTi-6Al-2Cb-1Ta-1Mo	R56210	0.03	0.10	0.005	0.015	5.5-6.5	...	...	0.15	Nickel	0.6/0.9	0.6/0.9
											Molybdenum	0.5/1.5	0.5/1.5
											Columbium	1.5/2.5	1.5/2.5
											Tantalum	0.5/1.5	0.5/1.5

Notes:

- Titanium constitutes the remainder of the composition.
- Single values are maximum.
- 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.
- Residual elements, total, shall not exceed 0.20 percent, with no single such element exceeding 0.05 percent. Residual elements need not be reported unless a report is specifically required by the purchaser. Residual elements are those elements (other than titanium) that are not listed in Table 1 for the particular classification, but which are inherent in the raw material or the manufacturing practice. Residual elements can be present only in trace amounts and they cannot be elements that have been intentionally added to the product.
- SAE/ASTM Unified Numbering System for Metals and Alloys.

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 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.

8. Chemical Analysis

8.1 A sample of the filler metal, or the stock from which it is made (see section 6, Summary of Tests, for limitations), shall be prepared for chemical analysis.

8.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E120, *Standard Methods for Chemical Analysis of Titanium and Titanium-Base 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 different package forms (straight lengths, coils with or without support, and spools) shall be as shown in Table 2.

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

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 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 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 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 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.

13.2 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.

13.2.1 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:

Table 2
Standard Sizes^a

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

Notes:

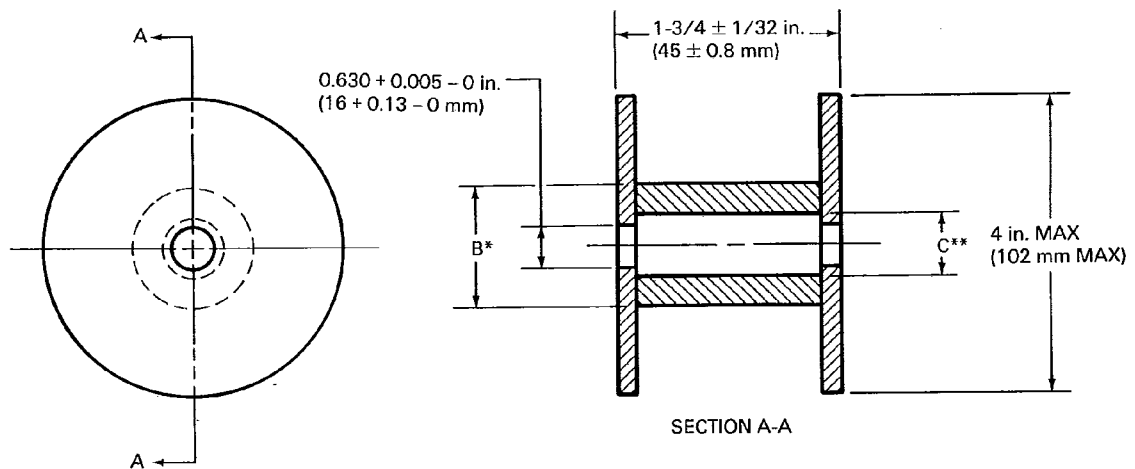
- a. Dimensions, sizes, tolerances, and package forms other than these shall be as agreed to by the purchaser and the supplier.
b. Length shall be 36 in. ± 1/4 in. (915 mm ± 6 mm).

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
Straight Lengths									
1/16 through 3/16	1.6 through 4.8	{ 10 50	4.5 23	—	—	—	—	—	—
Coils With Support and Coils Without Support									
1/16 through 3/16	1.6 through 4.8	{ 25 50 60	11 23 27	{ 2-1/2 or 4-5/8 4-5/8	{ 65 or 120 120	12 ± 1/8	305 ± 3	13-5/8 15-1/8 17 17-1/2	345 400 420 430
Spools									
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:

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

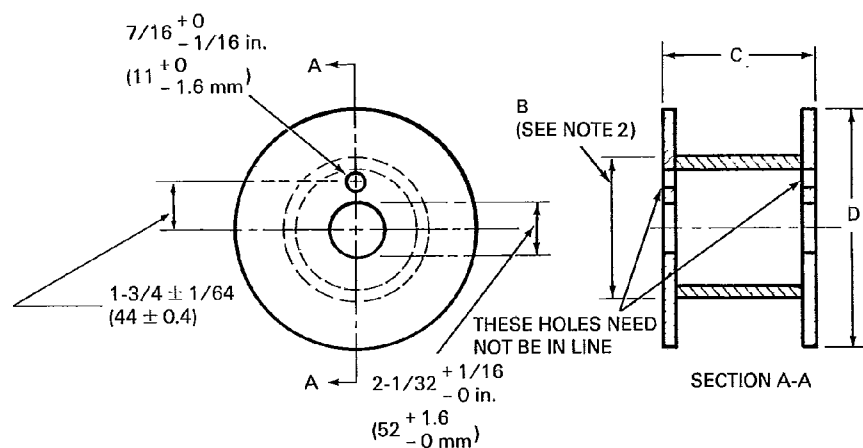


Notes:

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

**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 4 in. (100 mm) Spool



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

Figure 2 — Dimensions of 8 and 12 in. (200 and 300 mm) Spools

(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 1/2 in. (13 mm) at any location

13.2.2 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 3/4 in. (19 mm) at any location.

13.2.3 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.

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.

14.2 Coils without support shall have a tag containing this information securely attached to the filler metal at 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 at least 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 designations (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 label.

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 the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Appendix

Guide to AWS Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

(This Appendix is not a part of ANSI/AWS A5.16-90, *Specification for Titanium and Titanium Alloy Welding Electrodes and Rods*, but is included for information 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 "Ti" appears after "R" as a means of identifying the filler metals as unalloyed titanium or a titanium-base alloy. The numeral provides a means of identifying different variations in the composition. The filler letters "ELI" designate titanium alloy filler metals with extra low content of interstitial elements (carbon, oxygen, hydrogen, and nitrogen).

A2.3 Designations for individual alloys in this revision of the specification are different from those used in earlier documents. With the exception of ERTi-15, specific alloys now are identified by a number similar to the grade designation used in ASTM/ASME⁵ specifica-

tions for corresponding base metals. In the absence of a grade number in general usage for the Ti-6Al-2Cu-Ta-1Mo alloy, the number 15 was assigned arbitrarily to designate this classification of filler metal. See Table 1 and A1 for cross reference with the earlier designations.

A2.4 Tables 1 and A1 provide a correlation of the classifications in this revision with those in the previous (1970) revision and with other specifications for titanium alloy filler metals. The Aerospace Materials...ASTM/ASME Specifications listed are also widely used in industry. Table A1 presents a general correlation of the filler metals in these other specifications with those in this AWS specification.

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 the supplier, for material shipped in accordance with this specification, needs to 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 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

5. American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10007.

Table A1
Specification Cross Index*

Filler Metal		Base Metal		
AWS Classification		Aerospace Materials Specification (AMS)	Military Specification (MIL)	ASTM/ASME Grades
1990	1970			
ERTi-1	ERTi-1	4951	MIL-R-81558	1
ERTi-2	ERTi-2	—	MIL-R-81558	2
ERTi-3	ERTi-3	—	MIL-R-81558	3
ERTi-4	ERTi-4	—	MIL-R-81558	4
ERTi-5	ERTi-6Al-4V	4954	—	5
ERTi-5ELI	ERTi-6Al-4V-1	4956	MIL-R-81558	—
ERTi-6	ERTi-5Al-2.5Sn	4953	—	6
ERTi-6ELI	ERTi-5Al-2.5Sn-1	—	MIL-R-81558	—
ERTi-7	ERTi-0.2 Pd	—	—	7
ERTi-9	ERTi-3Al-2.5V	—	—	9
ERTi-9ELI	ERTi-3Al-2.5V-1	—	—	—
ERTi-12	ERTi-0.8Ni-0.3Mo	—	—	12
ERTi-15	ERTi-6Al-2Cb	—	MIL-R-81558	—
	1Ta-1Mo			

*Specifications are not exact duplicates. Information is supplied only for general comparison.

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/AWS A5.01.

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 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 drawn particularly to the section of that document, entitled "Health Protection and Ventilation."

A6. Welding Considerations

A6.1 Titanium and titanium alloys can be welded by gas tungsten arc, gas metal arc, plasma arc and electron beam welding processes. Titanium is a reactive metal and is sensitive to embrittlement by oxygen, nitrogen, and hydrogen, at temperatures above 500°F (260°C). Consequently, the metal must be protected from atmospheric contamination. This can be provided by shielding the metal with high purity inert gas in air or in a chamber, or by a vacuum of at least 10^{-4} torr. During arc welding, the titanium should be shielded from the atmosphere until it

has cooled below about 800°F (430°C). Adequate protection by auxiliary inert gas shielding can be provided when welding in air, but ventilation and exhaust at the arc should be carried out in such a manner that the protective atmosphere (arc shielding and backing) are not impaired. For critical applications, the welding should be done in a gas tight chamber thoroughly purged of air and filled with high purity inert gas.

A6.2 The titanium metal should be free of thick oxide and chemically clean prior to welding, as contamination from oxide, water, grease, or dirt will also cause embrittlement.

A6.3 Titanium welding rods should 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, should be removed before reusing the rod.

A6.4 Titanium can be successfully fusion welded to zirconium, tantalum, niobium, and vanadium, although the weld metal will be stronger and less ductile than the parent metals. Titanium should not be fusion welded to other commonly welded metals such as copper, iron, nickel, and aluminum, as brittle titanium intermetallic alloys are formed which produce extremely brittle welds.

A7. Description and Intended Use of Titanium and Titanium Alloy Electrodes and Rods

A7.1 ERTi-1, ERTi-2, ERTi-3, and ERTi-4. These alloys commonly are referred to as commercially pure (C.P.) titanium with the level of impurities and mechanical properties increasing slightly from ERTi-1 to ERTi-4. C.P. Grade 2 (equivalent to ERTi-2) is the most widely used titanium alloy for industrial applications because of its good balance of strength, formability, and weldability. Typical uses are in seawater and brackish water heat exchangers, chemical process heat exchangers, pressure vessels and piping systems, pulp bleaching systems, air pollution control scrubbers, and electrochemical and chemical storage tanks. These grades also have some uses in the aerospace industry.

A7.2 ERTi-5. This alloy is commonly referred to as "6-4" titanium and is probably the most widely used titanium alloy. Its high strength, ability to be heat treated, weldability, excellent fatigue strength, and hardness make this alloy excellent for industrial fans, pressure vessels, aircraft components, compressor blades, and automotive and jet engine parts.

A7.3 ERTi-5ELI. This filler metal is a slightly purer version of ERTi-5 with ELI (Extra Low Interstitial) content, which, in practice, refers primarily to the oxygen content. With special processing, this alloy can develop high fracture toughness. Primary uses are in surgical implants, cryogenic vessels, and airframe components.

A7.4 ERTi-6. This filler metal has good weldability, oxidation resistance, and stability and strength at elevated temperature. Typical uses include gas turbine engine casings, aerospace structural members at elevated temperatures near engines and wing leading edges, and chemical process equipment where high elevated temperature strength is required.

A7.5 ERTi-6ELI. This filler metal is a slightly purer version of ERTi-6 electrodes and rods with extra low interstitials (ELI). They are used to fabricate pressure vessels for liquified gases and other high pressure cryogenic vessels where better ductility and toughness with slightly lower strength are required.

A7.6 ERTi-7. Welds made with electrodes and rods of this classification probably are the most corrosion resistant titanium welds used in industrial applications. Mechanical and physical properties are similar to those of ERTi-2. This alloy extends the use of titanium into mildly reducing media, to much higher chloride levels, or where the environment fluctuates between oxidizing and reducing.

A7.7 ERTi-9. These electrodes and rods often are referred to as "half 6-4" because the major components are roughly half that found in ERTi-5. The primary use, to date, has been in welding hydraulic tubing and fittings for aircraft. Other industrial applications are being developed, particularly where the high strength and ability to maintain strength at elevated temperatures allow for more efficient design of pressure vessels. Corrosion resistance, in most environments, appears to be similar to, or slightly less than, that of weld metal from ERTi-2 electrodes.

A7.8 ERTi-9ELI. The reduced oxygen content of the ERTi-9ELI alloy results in slightly lower strength and improved toughness in comparison with weld metal from ERTi-9 electrodes.

A7.9 ERTi-12. Welds made with this filler metal offer improved corrosion resistance, especially to crevice corrosion in hot brines, and higher strength levels compared to similar welds made using ERTi-2 electrodes and rods. Uses in industrial applications are similar to those of ERTi-2 electrodes and rods, but can be extended to less oxidizing conditions.

A7.10 ERTi-15. Welds made with ERTi-15 electrodes and rods have excellent resistance to salt water corrosion combined with good toughness and moderate strength. Typical uses are the fabrication of submersible hulls, pressure vessels, etc., using base material of a matching composition.

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. ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, provides a means by which such tests can be incorporated into the purchase order.

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 Covered 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.