AWS UGFM:2010

AWS User's Guide to Filler Metals

American Welding Society

AWS User's Guide to Filler Metals

Second Edition 2010
(Supersedes UGFM:1995)

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International Standard Book Number: 978-0-87171-765-8
American Welding Society
550 N.W. LeJeune Road; Miami, FL 33126
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Printed in the United States of America

The *AWS User's Guide to Filler Metals* is a collection of commentary information selected from the 30 technical standards written by the AWS Committee on Filler Metal. The User's Guide provides descriptions of specific filler metals and their intended usage, as well as methods for classification, welding procedures, and safety considerations. Although reasonable care has been taken in the compilation and publication of the User's Guide to insure authenticity of the contents, no representation is made as to the accuracy or reliability of this information. The User's Guide is intended solely as a supplement to the AWS *Filler Metal Comparison Charts*, and should not be regarded as a substitute for the various AWS specifications to which it refers. This publication is subject to revision at any time.

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AWS User's Guide to Filler Metals

1. Scope

This document contains information on the many different types of filler materials available to industry. Welding considerations and intended applications for the various materials are provided to assist the user. The information has been extracted directly from 32 AWS filler material standards, and it is recommended that the user reference these documents for additional information.

Part A:
General Information

2. Provisions

Each of the AWS filler material specifications contain sections that establish provisions for material acceptance and certification, as well as safety considerations. Because this information is necessary for the proper application of all filler materials, these sections are included in this guide.

2.1 Acceptance. Acceptance of all welding materials 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 the 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 is normally conducted on material of the same classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. 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.

2.2 Certification. The act of placing the AWS specification and classification designations on the product packaging, or placing 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 tested 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, *Filler Metal Procurement Guidelines*.

2.3 Standard Sizes, Packaging, and Physical Attributes. Requirements for standard sizes and packages of welding filler metals and their physical attributes, such as product appearance and identification are prescribed in AWS A5.02/A5.02M:2007, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*. This specification applies to covered electrodes with both solid and tubular core wires; bare solid and tubular wires on spools, coils, and drums, or in straight lengths; and solid and sintered strip electrodes. It applies to all fusion welding processes, except brazing, braze welding, and thermal spraying, or granular metallic or mineral products, such as submerged arc fluxes, or other such products used in fusion welding processes.

The 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. The specification with the designation A5.02 uses U.S. Customary Units. The specification A5.02M uses SI Units.

2.4 General Safety Considerations. Safety and health issues and concerns are beyond the scope of these standards and, therefore, are not fully addressed herein. Some safety and health information can be found in the following paragraphs. Safety and health information is available from other sources.

2.4.1 Ventilation During Welding. Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding; they are:

(1) the dimensions of the space in which welding is performed (with special regard to the height of the ceiling)

(2) the number of welders and welding operators working in that space

(3) the 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 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 performed.

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 on health protection and ventilation. See also AWS F3.2 ventilation guide for weld fume, for more detailed descriptions of ventilation options.

The Safety and Health Fact Sheets listed below are published by the 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.

2.4.6 AWS Safety and Health Fact Sheets Index (SHF)

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*

19 *Laser Welding and Cutting Safety*

20 *Thermal Spraying Safety*

21 *Resistance Spot Welding*

22 *Cadmium Exposure from Welding & Allied Processes*

23 *California Proposition 65*

24 *Fluxes for Arc Welding and Brazing: Safe Handling and Use*

25 *Metal Fume Fever*

26 *Arc Viewing Distance*

27 *Thoriated Tungsten Electrodes*

28 *Oxyfuel Safety: Check Valves and Flashback Arrestors*

29 *Grounding of Portable and Vehicle Mounted Welding Generators*

30 *Cylinders: Safe Storage, Handling, and Use*

31 Eye and Face Protection for Welding and Cutting Operations

33 Personal Protective Equipment (PPE) for Welding & Cutting

34 Coated Steels: Welding and Cutting Safety Coneans

36 Ventilation for Welding & Cutting

37 Selecting Gloves for Welding & Cutting

AWS documents are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Part B:

Carbon and Low-Alloy Steels

3. Guide to Classification of Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding

3.1 Provisions. Excerpts from AWS A5.2/A5.2M:2007, *Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding.*

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

3.3 Classification System

3.3.1 The system for identifying the rod classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix "R [RM]" designates a rod. For A5.2, the numbers (45, 60, 65, and 100) indicate the required minimum tensile strength, as a multiple of 1000 psi, of the weld metal in a test weld made in accordance with specification A5.2. Similarly, for A5.2M, the numbers [30, 40, 45, and 69] indicate the required minimum tensile strength, as a multiple of 10 MPa, of the weld metal in a test weld made in accordance with specification A5.2M.

3.3.2 "G" Classification. This specification includes filler metals classified as R(X)XX-G [RMXX-G]. The "G" indicates that the filler metal is of a *general* classification. It is general because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing this classification is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from

all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal—one that otherwise would have to await a revision of the specification—to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition, again, for example).

3.4 Welding Considerations

3.4.1 The oxyfuel gas supplied to the torch should be adjusted to give a neutral or slightly reducing flame. This assures the absence of the oxidizing flame that could adversely influence weld quality. The extent of the excess fuel gas is measured by the length of the streamer (the so-called feather) of unburned fuel gas visible at the extremity of the inner cone. This streamer should measure about 1/8 to 1/4 the length of the inner cone of the flame. Excessively long streamers should be avoided, since they may add carbon to the weld metal.

3.4.2 In forehand welding, the torch flame points ahead in the direction of welding, and the welding rod precedes the torch flame. To distribute the heat and molten weld metal, it is necessary to use opposing oscillating motions for the flame and welding rod. This may cause excessive melting of the base metal and mixing of base metal and weld metal. Weld-metal properties may be altered.

3.4.3 In backhand welding, the torch flame points back at the molten metal, and the welding rod is interposed between the flame and molten metal. There is significantly less manipulation of the flame, the welding rod, and the molten metal. Therefore, a backhand weld is more likely to approach the chemical composition of undiluted weld metal.

3.5 Description and Intended Use of Carbon and Low-Alloy Steel Rods

3.5.1 Oxyfuel gas welding rods have no coverings to influence usability of the rod. Thus, the ability to weld in the vertical or overhead position is essentially a matter of welder's skill and can be affected to some degree by the chemical composition of the rod.

3.5.2 Class R45 [RM30] welding rods are used for the oxyfuel gas welding of steels, where the minimum tensile strength requirement of the steel does not exceed 45 ksi [300 MPa]. Class R45 [RM30] rods have a low carbon steel composition.

3.5.3 Class R60 [RM40] welding rods are used for the oxyfuel gas welding of carbon steels, where the minimum tensile strength requirement of the steel does not exceed 60 ksi [400 MPa]. Class R60 [RM40] rods have a carbon steel composition.

3.5.4 Class R65 [RM45] welding rods are used for the oxyfuel gas welding of carbon and low-alloy steels, where the minimum tensile strength requirement of the steel does not exceed 65 ksi [450 MPa]. Class R65 [RM45] welding rods may have either a low-alloy or an unalloyed carbon steel composition.

3.5.5 Class R100 [RM69] welding rods are used for the oxyfuel gas welding of low-alloy steels, where the minimum tensile strength requirement of the steel does not (AWS A5.2/A5.2M:2007) exceed 100 ksi [690 MPa] in the as-welded condition. Users are cautioned that response of the weld metal and base metal to postweld heat treatment may be different.

4. Guide to AWS Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding

4.1 Provisions. Excerpts from ANSI/AWS A5.1/A5.1M:2004, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

4.2 Introduction. The purpose of this guide is to correlate the electrode classifications with their intended applications so that the specification can be used effectively. Appropriate base metal specifications are referred to whenever that can be done and when it would be most helpful. Such references are intended only as examples rather than complete listings of the base metals for which each electrode classification is suitable.

4.3 Classification System

4.3.1 The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix letter "E" at the beginning of each classification designation stands for

electrode. The first two digits, 60 [43], for example, designate tensile strength of at least 60 ksi [430 MPa] of the weld metal, produced in accordance with the test assembly preparation section of the specification. In this document, the classification in U.S. Customary Units is followed by the SI Unit classification in brackets. The third digit designates position usability that will allow satisfactory welds to be produced with the electrode. Thus, the "1," as in E6010 [E4310], means that the electrode is usable in all positions (flat, horizontal, vertical, and overhead). The "2," as in E6020 [E4320] designates that the electrode is suitable for use in the flat position and for making fillet welds in the horizontal position. The "4," as in E7048 [E4948], designates that the electrode is suitable for use in vertical welding with downward progression and for other positions (see Table 4.1). The last two digits taken together designate the type of current with which the electrode can be used and the type of covering on the electrode, as listed in Table 4.1.

4.3.2 Optional designators are also used in this specification in order to identify electrodes that have met the mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and the purchaser. A "-1" designator following classification identifies an electrode which meets optional supplemental impact requirements at a lower temperature than required for the classification. An example of this is the E7024-1 [E4924-1] electrode which meets the classification requirements of E7024 [E4924] and also meets the optional supplemental requirements for toughness and improved elongation of the weld metal. Certain low-hydrogen electrodes may also have optional designators. An optional supplemental designator "HZ" following the four digit classification designators or following the "-1" optional supplemental

Table 4.1
Electrode Classification

AWS Classification				
A5.1	A5.1M	Type of Covering	Welding Position[a]	Type of Current[b]
E6010	E4310	High cellulose sodium	F, V, OH, H	dcep
E6011	E4311	High cellulose potassium	F, V, OH, H	ac or dcep
E6012	E4312	High titania sodium	F, V, OH, H	ac or dcen
E6013	E4313	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E6018[c]	E4318[c]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E6019	E4319	Iron oxide titania potassium	F, V, OH, H	ac, dcep, or dcen
E6020	E4320	High iron oxide	H-fillet	ac or dcen
			F	ac, dcep, or dcen
E6022[d]	E4322[d]	High iron oxide	F, H-fillet	ac or dcen
E6027	E4327	High iron oxide, iron powder	H-fillet	ac or dcen
			F	ac, dcep, or dcen
E7014	E4914	Iron powder, titania	F, V, OH, H	ac, dcep, or dcen
E7015	E4915	Low-hydrogen sodium	F, V, OH, H	dcep
E7016[c]	E4916[c]	Low-hydrogen potassium	F, V, OH, H	ac or dcep
E7018[c]	E4918[c]	Low-hydrogen potassium, iron powder	F, V, OH, H	ac or dcep
E7018M	E4918M	Low-hydrogen iron powder	F, V, OH, H	dcep
E7024[c]	E4924[c]	Iron power, titania	H-fillet, F	ac, dcep, or dcen
E7027	E4927	High iron oxide, iron powder	H-fillet	ac or dcen
			F	ac, dcep, or dcen
E7028[c]	E4928[c]	Low-hydrogen potassium, iron powder	H-fillet, F	ac or dcep
E7048	E4948	Low-hydrogen potassium, iron powder	F, OH, H, V-down	ac or dcep

Notes:

[a] The abbreviations, F, H, H-fillet, V, V-down, and OH indicate the welding positions as follows: F = Flat, H = Horizontal, H-fillet = Horizontal fillet, V = Vertical, progression upward (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]). V-down = Vertical, progression downward (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]), OH = Overhead (for electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E6018 [E4318], E7014 [E4914], E7015 [E4915], E7016 [E4916], E7018 [E4918], E7018M [E4918M], E7048 [E4948]).

[b] The term "dcep" refers to direct current electrode positive (dc, reverse polarity). The term "dcen" refers to direct current electrode negative (dc, straight polarity).

[c] Electrodes with supplemental elongation, notch toughness, absorbed moisture, and diffusible hydrogen requirements may be further identified as shown in Tables 2, 3, 10, and 11.

[d] Electrodes of the E6022 [E4322] classification are intended for single-pass welds only.