

AWS A5.32/A5.32M (ISO 14175 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*

AWS F3.2, *Ventilation Guide for Welding Fume*

2.2 ASTM Standards

ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*

ASTM A285/A285M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

ASTM A515/A515M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

ASTM A516/A516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

2.3 ANSI Standard

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

2.4 ISO Specifications

ISO 544, *Welding consumables — Technical delivery conditions for filler materials and fluxes — Type of product, dimensions, tolerances and markings*

ISO 15792-1, Amendment 1 (2011), *Welding consumables — Test methods — Part I: Test methods for all-weld metal test specimens in steel, nickel and nickel-alloys*

ISO 80000-1, *Quantities and units, Part 1: General*

3. Classification

3.1 Solid Electrodes

3.1.1 The solid electrodes (and rods) covered by the A5.18 specification utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition of the electrode (or rod) as specified in Table 1 and the as-welded mechanical properties of the weld metal as specified in Table 4. The GMAW weld test assembly in Figure 2, using CO₂ shielding gas, is required and sufficient to classify products offered as an electrode or an electrode and rod. The GTAW weld test assembly in Figure 2 is required for products offered as a rod only. The GTAW weld test assembly may be requested in addition to the GMAW weld test assembly as an option and as agreed upon between the purchaser and supplier.

3.1.1M The solid electrodes (and rods) covered by the A5.18M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the chemical composition of the electrode (or rod) as specified in Table 1 and the as-welded mechanical properties of the weld metal as specified in Table 4. The GMAW weld test assembly in Figure 2, using CO₂ shielding gas, is required and sufficient to classify products offered as an electrode or an electrode and rod. The GTAW weld test assembly in Figure 2 is required for products offered as a rod only. The GTAW weld test assembly may be requested in addition to the GMAW weld test assembly as an option and as agreed upon between the purchaser and supplier.

3.2 Composite Metal Cored and Composite Stranded Electrodes

3.2.1 The composite metal cored electrodes and composite stranded electrodes covered by this specification also utilize a classification system based upon U.S. Customary Units and are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2 and 4 respectively, and the shielding gas employed (see Figure 1).

Table 4
Mechanical Property Requirements (As Welded)

AWS Classification ^a A5.18 [A5.18M]	Shielding Gas ^{b,c}	Tensile Strength ^d psi [MPa]	Yield Strength ^e (minimum) psi [MPa]	Elongation ^f Percent (minimum)	Impact Strength ^{g,h,i} (minimum average) A5.18 [A5.18M]
ER70S-2 [ER49S-2]	CO ₂ (Classification C1)	70 000 [490]	58 000 [400]	22	20 ft-lbf @ -20°F [27J @ -30°C]
ER70S-3 [ER49S-3]					20 ft-lbf @ 0°F [27J @ -20°C]
ER70S-4 [ER49S-4]					Not Required
ER70S-6 [ER49S-6]					20 ft-lbf @ -20°F [27J @ -30°C]
ER70S-7 [ER49S-7]					20 ft-lbf @ -20°F [27J @ -30°C]
ER70S-8 [ER49S-8]					20 ft-lbf @ -20°F [27J @ -30°C]
ER70S-G [ER49S-G]	j				j

Composite Electrodes

E70C-3X [E49C-3X]	CO ₂ (Classification C1) or 75%–80% Argon/Bal CO ₂ (Classification M21)	70 000 [490]	58 000 [400]	22	20 ft·lbf @ 0°F [27J @ –20°C]		
E70C-6X [E49C-6X]					20 ft·lbf @ –20°F [27J @ –30°C]		
E70C-8X [E49C-8X]		70 000–90 000 [490–620]					
E70C-12X [E49C-12X]							
E70C-GX [E49C-GX]	j	70 000 [490]	Not Specified		j		
E70C-GSX [E49C-GSX]	j				Not Required		

^a Refer to Figure 1 for an explanation of the classification system.

^b The designations for the shielding gases (in brackets) are from AWS A5.32M/A5.32 (ISO 14175 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*. The use of a particular shielding gas for classification purposes shall not be construed to restrict the use of other gas mixtures. A filler metal tested with other gas blends may result in weld metal having different mechanical properties. Classification with other gas blends shall be as agreed upon between the purchaser and the supplier, unless designated by the C or M suffix.

^c Testing with 100% argon shielding is required when classification testing is based upon GTAW only.

^d Tensile Strengths are minimum unless specified otherwise.

^e Yield strength, minimum, at 0.2% offset.

^f Percent elongation in 2 in [50 mm] gage length (or 1.4 in [36 mm] gage length for the 0.350 in [9.0 mm] tensile specimen recommended in 12.1).

^g Both the highest and lowest of the five test values shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 ft-lbf [27 J]. One of the three remaining values may be lower than 20 ft-lbf [27 J], but not lower than 15 ft-lbf [20 J]. The average of the three shall not be less than the 20 ft-lbf [27 J] specified.

^h For classifications with the “N” (nuclear) optional supplemental designator, three additional specimens shall be tested at a temperature range of 60°F to 90°F [15°C to 32°C]. Two of the three shall equal, or exceed, 75 ft-lbf [100 J], and the third shall not be lower than 70 ft-lbf [95 J]. The average of the three shall equal, or exceed, 75 ft-lbf [100 J].

ⁱ Filler metal classification testing to demonstrate conformance to a specified minimum acceptable level for impact testing, i.e., minimum energy at specified temperature, can be met by testing and meeting the minimum energy requirement at any lower temperature. In these cases, the actual temperature used for testing shall be listed on the certification documentation when issued.

^j Not specified (as agreed upon between purchaser and supplier).

and yield strength for the A5.18M SI unit standard, and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the chemical composition, mechanical properties, and soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

7.2 The optional test for diffusible hydrogen in Clause 15, Diffusible Hydrogen Test, is not required for classification (see Note e of Table 3).

Table 3
Required Tests

AWS Classification ^a A5.18 [A5.18M]	Chemical Analysis		Radiographic Test	Tension Test	Bend Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal					
Solid Electrodes							
ER70S-2 [ER49S-2]	Required	Not Required	Required	Required	Not Required	Required	f
ER70S-3 [ER49S-3]							
ER70S-6 [ER49S-6]							
ER70S-7 [ER49S-7]							
ER70S-8 [ER49S-8]							
ER70S-4 [ER49S-4]						Not Required	
ER70S-G [ER49S-G]						e	
Composite Electrodes							
E70C-3X [E49C-3X]	Not Required	Required	Required	Required	Not Required	Required	f
E70C-6X [E49C-6X]							
E70C-8X ^b [E49C-8X ^b]							
E70C-12X [E49C-12X]							
E70C-GX [E49C-GX]						e	
E70C-GSX ^c [E49C-GSX ^c]		Not Required	Not Required	Required ^d	Required	Not Required	

^a Refer to Figure 1 for an explanation of the classification system.

^b Welding shall be performed using direct current, electrode negative polarity.

^c Intended for single pass welding.

^d Transverse tensile test. All others are all-weld-metal tension tests.

^e Not specified but as agreed upon between purchaser and supplier.

^f Optional diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label. See also A2.2 and A8.2 in Annex A.

metal is transferred in drops generally larger in diameter than the electrode and at a rate of from 10 to 20 per second (globular transfer). The transition current is also dependent, to some extent, on the chemical composition of the electrode. For 1/16 in [1.6 mm] diameter carbon steel electrodes, a transition current of 270 amperes (direct current, electrode positive [dcep]) is common. Alternating current is not recommended for this type of welding because it does not produce a stable arc.

A6.2.3 Pulsed Spray. Metal transfer in pulsed spray welding is similar to that of the spray transfer described above, but it occurs at a lower average current. The lower average current is made possible by rapid pulsing of the welding current between a high level, where metal will transfer rapidly in the spray mode, and a low level, where no transfer will take place. At a typical rate of 60 to 120 pulses per second, a melted drop is formed by the low current arc, which is then “squeezed off” by the high current pulse. This permits all-position welding.

A6.3 Globular Transfer. The mode of transfer that characterizes 100% CO₂ [AWS A5.32M/A5.32 (ISO 14175 MOD), Classification C1] as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This shortens the arc length causing the arc to be “buried” and results in deeper penetration and better containment of spatter within the weld pool. Electrodes of 0.045 in through 1/16 in [1.2 mm through 1.6 mm] diameter normally are used at welding currents in the range of 275 to 400 amperes (dcep), for this type of transfer. The rate at which droplets (globules) are transferred ranges from 20 to 70 per second, depending on the size of the electrode, the amperage, polarity, and arc voltage.

A6.4 Short Circuiting Transfer. This mode of transfer is obtained with small diameter electrodes (0.030 to 0.045 in [0.8 to 1.2 mm]) using low arc voltages and amperages, and a power source designed for short circuiting transfer. The electrode short-circuits to the weld metal, usually at a rate of from 50 to 200 times per second. Metal is transferred with each short circuit, but not across the arc. Short circuiting gas metal arc welding of carbon steel is done most commonly with mixtures of argon and CO₂ as the shielding gas or with CO₂ [AWS A5.32M/A5.32 (ISO 14175 MOD), Classification C1] alone. The penetration of such welds is greater with CO₂ than it is with argon-CO₂ mixtures. Mixtures of 50 to 80% argon with CO₂ remainder can be advantageous for thin material. They provide low penetration, higher short circuiting rates, and lower minimum currents and voltages than CO₂ alone does.

A7. Description and Intended Use of Electrodes and Rods

A7.1 Shielding Gas Consideration. Solid electrodes in this specification are classified with CO₂ gas shielding. However this is not to preclude their use with other shielding gases. The user should be aware that use with gases of lower oxidizing potential (e.g., argon plus 10% CO₂) will result in greater Mn and Si recovery in the weld metal and correspondingly higher strength.

A7.2 ER70S-2 [ER49S-2]. Electrodes and rods of the ER70S-2 [ER49S-2] classification are primarily used for single-pass welding of killed, semi-killed, and rimmed steels, but may be used for some multipass applications. Because of the added deoxidants, these filler metals can be used for welding steels that have a rusty or dirty surface, with a possible sacrifice of weld quality depending on the condition of the surface. ER70S-2 [ER49S-2] filler metals are used extensively to produce high quality, high toughness welds with the GTAW process. These filler metals are also well suited for use in single side, melt through welding without a protective root shielding gas on the backside of the joint. Typical specifications for these steels are ASTM A36, A285-C, A515-70, and A516-70, which have UNS numbers K02600, K02801, K03101, and K02700, respectively.

A7.3 ER70S-3 [ER49S-3]. Electrodes and rods of the ER70S-3 [ER49S-3] classification are intended for welding single-pass and multi-pass welds. Typical base metal specifications are often the same as those for the ER70S-2 [ER49S-2] classification. Electrodes of the ER70S-3 [ER49S-3] classification are the most widely used of the GMAW electrodes classified under this specification.

A7.4 ER70S-4 [ER49S-4]. Electrodes and rods of the ER70S-4 [ER49S-4] classification are intended for welding steel where conditions require more deoxidation than is provided by the ER70S-3 [ER49S-3] filler metal. Typical base metal specifications are often the same as those for the ER70S-2 [ER49S-2] classification. This classification does not require impact testing.

A7.5 ER70S-6 [ER49S-6]. Electrodes and rods of the ER70S-6 [ER49S-6] classification are intended for both single- and multiple-pass welding. They are especially suited for sheet metal applications, where smooth weld beads are de-