AFM ER70S-2

AWS/SFA A5.18

AFM ER70S-2 is used primarily for single-pass welding of killed, semi-killed, and rimmed steels, but may also be used for some multipass applications. Because of the added deoxidants, **AFM ER70S-2** 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. Typical specifications for these steels are ASTM A36, A285-C, A515-55 and A516-70, which have UNS numbers K02600, K02801, K02001, and K02700, respectively.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.07	Mo	(a)
Mn	0.90-1.40	V	(a)
Si	0.40-0.70	Cu	0.50
P	0.025	Ti	0.05-0.15
S	0.035	Zr	0.02-0.12
Ni	(a)	Al	0.05-0.15
Cr	(a)		

All values are considered maximum, unless otherwise noted.

a. These residual elements shall not exceed 0.50 in total.

Typical Mechanical Properties:

Tensile Strength, psi	80,000
MPa	552
Yield Strength, psi	65,000
MPa	450
Elongation, (%, 2”)	25
Charpy V-Notch (ft.-lbs. @ -20°F)	28

Standard Sizes:

.030 (0.8mm), .035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER70S-3

AWS/SFA A5.18

AFM ER70S-3 is intended for welding single-pass and multi-pass welds. It provides sufficient deoxidation to allow welding over light mill scale. Typical base metal specifications are often the same as those for **AFM ER70S-2**.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.06-0.15	Ni	(a)
Mn	0.90-1.40	Cr	(a)
Si	0.45-0.75	Mo	(a)
P	0.025	V	(a)
S	0.035	Cu	0.50

All values are considered maximum, unless otherwise noted.

a. These residual elements shall not exceed 0.50 in total.

Typical Mechanical Properties:

Tensile Strength, psi	78,000
MPa	538
Yield Strength, psi	62,000
MPa	427
Elongation, (%, 2”)	22
Charpy V-Notch (ft.-lbs. @ -20°F)	38

Standard Sizes:

.030 (0.8mm), .035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER70S-6

AWS/SFA A5.18

AFM ER70S-6 is intended for both single- and multi-pass welding. It is especially suited for sheet metal applications, where smooth weld beads are desired, and structural and plate steels that have moderate amounts of rust or mill scale. **AFM ER70S-6** withstands high currents with CO_2 shielding, even when welding rimmed steels. Typical base metal specifications are often the same as those for **AFM ER70S-2**.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.06-0.15	Ni	(a)
Mn	1.40-1.85	Cr	(a)
Si	0.80-1.15	Mo	(a)
P	0.025	V	(a)
S	0.035	Cu	0.50

All values are considered maximum, unless otherwise noted.

a. These residual elements shall not exceed 0.50 in total.

Typical Mechanical Properties:

Tensile Strength, psi	82,000
MPa	566
Yield Strength, psi	66,000
MPa	485
Elongation, (%, 2")	22
Charpy V-Notch (ft.-lbs. @ -20°F)	34

Standard Sizes:

.030 (0.8mm), .035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

2#, 10#, 30#, 33#, 44# spools & 550# drums

AFM ER80S-D2

AWS/SFA A5.28

AFM ER80S-D2 contains 1/2% molybdenum for increased strength and a high level of deoxidiziers (Mn and Si) to control porosity when welding with CO2 as the shielding gas. It will give radiographic quality welds with excellent bead appearance in both ordinary and difficult-to-weld carbon and low-alloy steels. **AFM ER80S-D2** exhibits excellent out-of-position welding characteristics with the short circuiting and pulsed arc processes. The combination of weld soundness and strength makes **AFM ER80S-D2** suitable for single and multiple-pass welding of a variety of carbon and low-alloy, higher strength steels in both the as welded and postweld heat-treated conditions.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.07-0.12	Ni	0.15
Mn	1.60-2.10	Mo	0.40-0.60
Si	0.50-0.80	Cu	0.50
P	0.025	Total Other	0.50
S	0.025		

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:

See table on page 67.

Standard Sizes:

.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER80S-B2

AWS/SFA 5.28

AFM ER80S-B2 is used to weld 1/2Cr-1/2Mo, 1Cr-1/2Mo, and 1-1/4Cr-1/2Mo steels for elevated temperatures and corrosive service. It is also used for joining dissimilar combinations of Cr-Mo and carbon steels. All transfer modes of the GMAW process may be used. Careful control of preheat, interpass temperatures, and postheat is essential to avoid cracking. **AFM ER80S-B2** is classified after postweld heat treatment. Special care must be used when using it in the as-welded condition due to higher strength levels.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.07-0.12	Ni	0.20
Mn	0.40-0.70	Cr	1.20-1.50
Si	0.40-0.70	Mo	0.40-0.65
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

Standard Sizes:
.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER70S-B2L

AWS/SFA A5.28

AFM ER70S-B2L is identical to **AFM ER80S-B2** except for the low-carbon content (0.05 percent maximum) and thus the lower strength levels. It exhibits greater resistance to cracking and is more suitable for welds to be left in the as-welded condition or when the accuracy of the postweld heat treatment operation is questionable. The classification was previously ER80S-B2L. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.05	Ni	0.20
Mn	0.40-0.70	Cr	1.20-1.50
Si	0.40-0.70	Mo	0.40-0.65
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

AFM ER90S-B3

AWS/SFA A5.28

AFM ER90S-B3 is used to weld the 2-1/4Cr-1Mo steels used for high-temperature/high-pressure piping and pressure vessels. It may also be used for joining combinations of Cr-Mo and carbon steel. All GMAW modes may be used. Careful control of preheat, interpass temperatures, and postweld heat treatment is essential to avoid cracking. **AFM ER90S-B3** is classified after postweld heat treatment. Special care must be used when using it in the as-welded condition due to higher strength levels.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.07-0.12	Ni	0.20
Mn	0.40-0.70	Cr	2.30-2.70
Si	0.40-0.70	Mo	0.90-1.20
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

Standard Sizes:
.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER80S-B3L

AWS/SFA A5.28

AFM ER80S-B3L is identical to **AFM ER90S-B3** except for the low-carbon content (0.05 percent maximum) and, therefore, the lower strength levels. It exhibits greater resistance to cracking and is more suitable for welds to be left in the as-welded condition. **AFM ER80S-B3L** was previously ER90S-B3L. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.05	Ni	0.20
Mn	0.40-0.70	Cr	2.30-2.70
Si	0.40-0.70	Mo	0.90-1.20
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

AFM ER80S-B6

AWS/SFA A5.28

AFM ER80S-B6 contains 4.0 to 6.0 percent chromium and about 0.50 percent molybdenum. It is used for welding material of similar composition, usually in the form of pipe or tubing. It is air-hardening material and, therefore, when welding with **AFM ER80S-B6**, preheat and postweld heat treatment are required. **AFM ER80S-B6** is similar to that previously classified as ER502 in AWS A5.9-81.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.10	Ni	0.60
Mn	0.40-0.70	Cr	4.50-6.00
Si	0.50	Mo	0.45-0.65
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

Standard Sizes:
.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER80S-B8

AWS/SFA A5.28

AFM 80S-B8 contains 8.0 to 10.5 percent chromium and about 1.0 percent molybdenum. It is used for welding base metal of similar compositions, usually in the form of pipe or tubing. It is air-hardening material and, therefore, when welding with **AFM ER80S-B8**, preheating and postweld heat treatment are required. **AFM ER80S-B8** is similar to that previously classified as ER505 in AWS A5.9-81.

Chemical Composition Requirements for Solid Electrodes and Rod:

C	0.10	Ni	0.50
Mn	0.40-0.70	Cr	8.00-10.50
Si	0.50	Mo	0.80-1.20
P	0.025	Cu	0.35
S	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

Standard Sizes:
.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), 1/8 (3.2mm), & 5/32 (4.0mm)

AFM ER90S-B9

AWS/SFA A5.28

AFM ER90S-B9 is a 9Cr-1Mo solid wire modified with niobium (columbium) and vanadium designed to provide strength, toughness, fatigue life, oxidation resistance and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of **AFM ER90S-B9**, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating the problems associated with dissimilar welds.

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.07-0.13	Mo	0.80-1.10
Mn	1.25	V	0.15-0.25
Si	0.15-0.30	Al	0.04
P	0.010	Cu	0.20
S	0.010	Cr	8.00-9.50
Ni	1.00	Total Other	0.50
Cb (Nb)	0.02-0.10		

All values are considered maximum, unless otherwise noted.

Applications:

AFM ER90S-B9 is used for welding A213-T91 Tube, A335-P91 Pipe, and A387 Gr. 91 Plate.

Minimum Tension Test Requirements;

See table on page 67.

Standard Sizes:

.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), & 1/8 (3.2mm)

AFM ER80S-Ni1

AWS/SFA A5.28

AFM ER80S-Ni1 deposits weld metal similar to **AFM E8018-C3** electrodes, and is used for welding low-alloy high-strength steels requiring good toughness at temperatures as low as -50°F (-46°C).

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.12	Cr	0.15
Mn	1.25	Mo	0.35
Si	0.40-0.80	V	0.05
P	0.025	Cu	0.35
S	0.025	Total Other	0.50
Ni	0.80-1.10		

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:

See table on page 67.

Standard Sizes:

.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), & 1/8 (3.2mm)

AFM ER80S-Ni2

AWS/SFA A5.28

AFM ER80S-Ni2 deposits weld metal similar to **AFM E8018-C1** electrodes. Typically, it is used for welding 2-1/2 percent nickel steels and other materials requiring good toughness at temperatures as low as -80°F (-62°C).

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.12	S	0.025
Mn	1.25	Ni	2.00-2.75
Si	0.40-0.80	Cu	0.35
P	0.025	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:

See table on page 67.

Standard Sizes:

.035 (0.9mm), .045 (1.2mm), 1/16 (1.6mm), 3/32 (2.4mm), & 1/8 (3.2mm)

AFM ER100S-1

AWS/SFA A5.28

AFM ER100S-1 deposits high-strength, very tough weld metal for critical applications. Originally developed for welding HY80 steels for military applications, it is also used for a variety of structural applications where tensile strength requirements exceed 100 ksi (690 MPa), and excellent toughness is required to temperatures as low as -60°F (-51°C).

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.08	Mo	0.25-0.55
Mn	1.25-1.80	V	0.05
Si	0.20-0.55	Ti	0.10
P	0.010	Zr	0.10
S	0.010	Al	0.10
Ni	1.40-2.10	Cu	0.25
Cr	0.30	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

AFM ER110S-1

AWS/SFA A5.28

AFM ER110S-1 deposits high-strength, very tough weld metal for critical applications. Originally developed for welding HY100 steels for military applications, it is also used for a variety of structural applications where tensile strength requirements exceed 100 ksi (690 MPa), and excellent toughness is required to temperatures as low as -60°F (-51°C).

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.09	Mo	0.25-0.55
Mn	1.40-1.80	V	0.04
Si	0.20-0.55	Ti	0.10
P	0.010	Zr	0.10
S	0.010	Al	0.10
Ni	1.90-2.60	Cu	0.25
Cr	0.50	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

AFM ER120S-1

AWS/SFA A5.28

AFM ER120S-1 deposits high-strength, very tough weld metal for critical applications. Originally developed for welding HY100 steels for military applications, it is also used for a variety of structural applications where tensile strength requirements exceed 100 ksi (690 MPa), and excellent toughness is required to temperatures as low as -60°F (-51°C).

Chemical Composition Requirements for Solid Electrodes and Rods:

C	0.10	Mo	0.30-0.65
Mn	1.40-1.80	V	0.03
Si	0.25-0.60	Ti	0.10
P	0.010	Zr	0.10
S	0.010	Al	0.10
Ni	2.00-2.80	Cu	0.25
Cr	0.60	Total Other	0.50

All values are considered maximum, unless otherwise noted.

Minimum Tension Test Requirements:
See table on page 67.

AFM RG45

AWS/SFA A5.2

AFM RG45 is a copper coated, low carbon steel welding rod used for the welding of steel where the minimum tensile strength requirement does not exceed 45 ksi (310 MPa).

Chemical Composition Requirements for Welding Rods:

C	0.08	Cu	0.30
Mn	0.05	Cr	0.20
Si	0.10	Ni	0.30
P	0.035	Mo	0.20
S	0.040	Al	0.02

All values are considered maximum, unless otherwise noted.

Tension Test Requirements (as welded):
Not specified.

Standard Packaging & Sizes:
50# bulk packages in diameters: 1/16 (1.6), 3/32 (2.0), 1/8 (3.2), 5/32 (4.0), 3/16 (4.8), & 1/4 (6.4)

AFM RG60

AWS/SFA A5.2

AFM RG60 is used for the oxyfuel gas welding of carbon steels, where the minimum tensile strength requirement does not exceed 60 ksi (415 MPa).

Chemical Composition Requirements for Welding Rods:

C	0.15	Cu	0.30
Mn	0.90-1.40	Cr	0.20
Si	0.10-0.35	Ni	0.30
P	0.035	Mo	0.20
S	0.035	Al	0.02

All values are considered maximum, unless otherwise noted.

Tension Test Requirements (as welded):

Minimum Tensile Strength, psi	60,000
Elongation in 1” (%), min.	20

Standard Packaging & Sizes:
50# bulk packages in diameters: 1/16 (1.6), 3/32 (2.0), 1/8 (3.2), 5/32 (4.0), 3/16 (4.8), & 1/4 (6.4)

Table 1
Minimum Tension Test Requirements

AWS Classification	Shielding Gas*	Tensile Strength		Yield Strength		Elongation Percent	Testing Condition
		psi	MPa	psi	MPa		
ER70S-B2L	Argon/1-5% O_2	75,000	515	58,000	400	19	PWHT**
ER80S-B2		80,000	550	68,000	470	19	
ER80S-B3L		80,000	550	68,000	470	17	
ER90S-B3		90,000	620	78,000	540	17	
ER80S-B6 ER80S-B8		80,000	550	68,000	470	17	
ER90S-B9	Argon/5% O_2	90,000	620	60,000	410	16	
ER80S-Ni1	Argon/1-5% O_2	80,000	550	68,000	470	24	As-Welded
ER80S-Ni2		80,000	550	68,000	470	24	PWHT**
ER80S-D2	CO_2	80,000	550	68,00	470	17	As-Welded
ER100S-1	Argon/2% O_2	100,000	690	88,000	610	16	As-Welded
ER110S-1		110,000	760	95,000	660	15	
ER120S-1		120,000	830	105,000	730	14	

Notes:

* The use of a particular shielding gas for classification purposes shall not be construed to restrict the use of shielding gas mixtures. A filler metal tested with other gas blends, such as Argon/O_2 or Argon/CO_2 may result in weld metal having different strength and elongation. Classification with other gas blends shall be agreed upon between the purchaser and supplier.

** Postweld heat-treated condition in accordance to Table 2.

Table 2
Preheat, Interpass, and Postweld Heat Treatment Temperatures

	Preheat and Interpass Temperature*		PWHT Temperature*	
AWS Classification	°F	°C	°F	°C
ER80S-B2 ER70S-B2L	275 – 325	135 – 165	1150 ± 25	620 ± 15
ER90S-B3 ER80S-B3L	375 – 425	185 – 215	1275 ± 25	690 ± 15
ER80S-B6	350 – 450	177 – 232	1375 ± 25	745 ± 15
ER80S-B8	400 – 500	205 – 260	1375 ± 25	745 ± 15
ER90S-B9	300 – 500	150 – 260	1375 ± 25	745 ± 15
ER80S-Ni2	275 – 325	135 – 165	1150 ± 25	620 ± 15
ER80S-D2 ER80S-Ni1 ER100S-1 ER110S-1 ER120S-1	275 – 325	135 – 165	None**	None**

Notes:

* These temperatures are specified for testing under this specification and are not to be considered as recommendations for preheat, interpass, and postweld heat treatment in production welding. The requirements for production welding must be determined by the user. They may or may not differ from those called here.

** These classifications are normally used in the as-welded condition.

GENERAL WELDING TIPS

I. Gas metal arc welding (GMAW) can be divided into four categories based on the mode of metal transfer: (1) spray, (2) pulsed spray, (3) globular, and (4) short circuiting transfer. In the spray, pulsed spray, and globular modes, transfer occurs as distinct droplets that are detached from the electrode, transferring along the arc column into the weld pool. In the short circuiting mode, the metal deposited during frequent short circuiting of the electrode in the molten pool.

II. **Spray Transfer.** The spray transfer mode, for low-alloy steel, is most commonly obtained with argon shielding gas mixtures with up to 5 percent oxygen or carbon dioxide. A characteristic of these shielding gas mixtures is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

Spray transfer with argon-oxygen or argon-carbon dioxide shielding gas is, primarily, a function of current density, polarity, and resistance heating of the electrode. The high droplet rate (approximately 250 droplets per second) develops suddenly above a critical current level, commonly referred to as the *transition current* (for each size electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode 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 (1.6mm) diameter low-alloy 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.

III. **Pulsed Spray Transfer.** 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.

IV. **Globular Transfer.** The mode of transfer that charcterizes 100 percent CO2 as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This buries the arc and produces deep penetration. Electrodes of 0.045 and 1/16 in. (1.2 and 1.6 mm) diameter normally are used at welding currents in the range of 275 – 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.

V. **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 low-alloy steel is done most commonly with mixtures of argon and CO2 as the shielding gas, with CO2 alone, and occasionally with mixtures of helium-argon-CO2. Penetration of welds made with CO2 shielding gas is greater than with argon-CO2 mixtures, but mixtures containing substantial amounts of argon or helium generally result in superior weld metal impact properties. Shielding gas mixtures of 50 to 90 percent argon-remainder CO2 or 50 to 90 percent helium-remainder CO2 result in higher short circuiting rates and lower minimum currents and voltages than does CO2 shielding alone. This can be an advantage when welding thin plate or in the achievement of superior impact properties.