

SPECIFICATION FOR CARBON STEEL ELECTRODES AND RODS FOR GAS SHIELDED ARC WELDING



SFA-5.18



(Identical with AWS Specification A5.18-93)

1. Scope

This specification prescribes requirements for the classification of carbon steel electrodes (solid, composite stranded and composite metal cored) and rods (solid) for gas metal arc (GMAW), gas tungsten arc (GTAW), and plasma arc (PAW) welding.

PART A — GENERAL REQUIREMENTS

2. Classification

2.1 The solid electrodes (and rods) covered by this specification are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The composite stranded electrodes and composite metal cored electrodes covered by this specification are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 and the shielding gas employed.

2.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except the composite stranded electrodes classified as E70C-XC may also be classified as E70C-XM, or both.

2.3 The welding electrodes and rods classified under this specification are intended for gas shielding arc welding, but that is not to prohibit their use with any other process (or any other shielding gas, or combination of shielding gases) for which they are found suitable.

3. Acceptance

Acceptance¹ of the electrodes and rods shall be in accordance with the provisions of ANSI/AWS A 5.01, *Filler Metal Procurement Guidelines*².

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

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

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

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

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES AND RODS

AWS Classification ^b	UNS Number ^b	Weight Percent ^a												
		C	Mn	Si	P	S	Ni	Cr	Mo	V	Cu ^d	Ti	Zr	Al
ER70S-2	K10726	0.07	0.90 to 1.40	0.40 to 0.70	0.025	0.035	(e)	(e)	(e)	(e)	0.50	0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
ER70S-3	K11022	0.06 to 0.15	0.90 to 1.40	0.45 to 0.75	0.025	0.035	(e)	(e)	(e)	(e)	0.50	—	—	—
ER70S-4	K11132	0.07 to 0.15	1.00 to 1.50	0.65 to 0.85	0.025	0.035	(e)	(e)	(e)	(e)	0.50	—	—	—
ER70S-5	K11357	0.07 to 0.19	0.90 to 1.40	0.30 to 0.60	0.025	0.035	(e)	(e)	(e)	(e)	0.50	—	—	0.50 to 0.90
ER70S-6	K11140	0.06 to 0.15	1.40 to 1.85	0.80 to 1.15	0.025	0.035	(e)	(e)	(e)	(e)	0.50	—	—	—
ER70S-7	K11125	0.07 to 0.15	1.50 to 2.00 ^f	0.50 to 0.80	0.025	0.035	(e)	(e)	(e)	(e)	0.50	—	—	—
ER70S-G	—	Not Specified ^g												

Not Specified^g

NOTES:

- Single values are maximum.
- The letter "N" as a suffix to a classification indicates that the weld metal is intended for the core belt region of nuclear reactor vessels, as described in the Annex to the specification. This suffix changes the limits on the phosphorus, vanadium and copper as follows:
P = 0.012% maximum
V = 0.05% maximum
Cu = 0.08% maximum
- SAE/ASTM Unified Numbering System for Metals and Alloys.
- Copper due to any coating on the electrode or rod plus the copper content of the filler metal itself, shall not exceed the stated 0.50% max.
- These residual elements shall not exceed 0.50% in total.
- In this classification, the maximum Mn may exceed 2.0%. If it does, the maximum C must be reduced 0.01% for each 0.05% increase in Mn or part thereof.
- Chemical requirements are not specified but there shall be no intentional addition of Ni, Cr, Mo, and V. Composition shall be reported. Requirements are those agreed to by the purchaser and the supplier.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR WELD METAL FROM COMPOSITE ELECTRODES

AWS Classification ^a	UNS Number ^b	Shielding gas ^c	Weight Percent ^d									
			C	Mn	Si	S	P	Ni	Cr	Mo	V	Cu
Multiple-Pass Classifications												
E70C-3X	W07703	75-80% Ar/Balance CO ₂ or CO ₂	0.12	1.75	0.90	0.03	0.03	(e)	(e)	(e)	(e)	0.50
E70C-6X	W07706	75-80% Ar/Balance CO ₂ or CO ₂	0.12	1.75	0.90	0.03	0.03	(e)	(e)	(e)	(e)	0.50
E70C-G(X)	—	(f)	Not Specified ^g									
Single-Pass Classifications												
E70C-GS(X)	—	(f)	Chemical Requirements not Specified ^h									

NOTES:

- The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO₂ shielding. "M" designates 75-80% Ar/balance CO₂. For E70C-G and E70C-GS, the final "C" or "M" may be omitted if these gases are not used for classification.
- SAE/ASTM Unified Numbering System for Metals and Alloys.
- Use of a shielding gas other than that specified will result in different weld metal composition.
- Single values are maximums.
- To be reported if intentionally added; the sum of Ni, Cr, Mo, and V shall not exceed 0.50%.
- Shielding gas shall be as agreed upon between purchaser and supplier.
- Composition shall be reported; the requirements are those agreed to between purchaser and supplier.
- The composition of weld metal from this classification is not specified since electrodes of this classification are intended only for single pass welds. Dilution, in such welds, usually is quite high.

TABLE 3
TENSION TEST REQUIREMENTS (AS WELDED)

AWS Classification ^a	Shielding Gas	Tensile Strength (minimum)		Yield Strength ^b (minimum)		Elongation Percent (minimum)
		psi	MPa	psi	MPa	
ER70S-2 ER70S-3 ER70S-4 ER70S-5 ER70S-6 ER70S-7	CO ₂ ^c	70 000	480	58 000	400	22
ER70S-G	d	70 000	480	58 000	400	22
E70C-3X E70C-6X	75-80% Ar/balance CO ₂ or CO ₂	70 000	480	58 000	400	22
E70C-G(X)	d	70 000	480	58 000	400	22
E70C-GS(X)	d	70 000	480	Not Specified		Not Specified

NOTES:

- The final X shown in the classification represents a "C" or "M" which corresponds to the shielding gas with which the electrode is classified. The use of "C" designates 100% CO₂ shielding; "M" designates 75-80% Ar/balance CO₂. For E70C-G and E70C-GS, the final "C" or "M" may be omitted.
- Yield strength at 0.2% offset and elongation in 2 in. (51 mm) gage length.
- CO₂ = carbon dioxide shielding gas. The use of CO₂ for classification purposes shall not be construed to preclude the use of Ar/CO₂ or Ar/O₂ shielding gas mixtures. A filler metal tested with gas blends, such as Ar/O₂, or Ar/CO₂, may result in weld metal having higher strength and lower elongation.
- Shielding gas shall be as agreed to between purchaser and supplier.

TABLE 4
IMPACT TEST REQUIREMENTS (AS WELDED)

AWS Classification	Average Impact Strength ^{a,b} (Minimum)
ER70S-2	20 ft · lbf at -20°F (27J @ -29°C)
ER70S-3	20 ft · lbf at 0°F (27J @ -18°C)
ER70S-4	Not Required
ER70S-5	Not Required
ER70S-6	20 ft · lbf at -20°F (27J @ -29°C)
ER70S-7	20 ft · lbf at -20°F (27J @ -29°C)
ER70S-G	As agreed between supplier and purchaser
E70C-G(X)	As agreed between supplier and purchaser
E70C-3X	20 ft · lbf at 0°F (27J @ -18°C)
E70C-6X	20 ft · lbf at -20°F (27J @ -29°C)
E70C-GS(X)	Not required

NOTES:

- Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. Two of the remaining three values shall equal or exceed 20 ft · lbf; one of the three remaining values may be lower than 20 ft · lbf but not lower than 15 ft · lbf. The average of the three shall not be less than the 20 ft · lbf specified.
- For classifications with the "N" (nuclear) designation, three additional specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft · lbf (102J), and the third shall not be lower than 70 ft · lbf (95J). Average of the three values shall equal, or exceed, 75 ft · lbf (102J).

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 ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁴

PART B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

6.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, the 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 Sections 8 through 12.

6.2 The optional test for diffusible hydrogen in Section 14, Diffusible Hydrogen Test, is not required for classification. See Note (c) of Table 5.

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

TABLE 5
REQUIRED TESTS

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Bend Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal					
Solid Electrodes							
ER70S-2	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-3	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-4	Required	Not Required	Required	Required	Not Required	Not Required	c
ER70S-5	Required	Not Required	Required	Required	Not Required	Not Required	c
ER70S-6	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-7	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-G	Required	Not Required	Required	Required	Not Required	Not Required	c
Composite Electrodes							
E70C-3X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-6X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-G(X)	Not Required	Required	Required	Required	Not Required	Not Required	c
E70C-GS(X) ^a	Not Required	Not Required	Not Required	Required ^b	Required	Not Required	c

NOTES:

- Intended for single-pass welding.
- Transverse tension test. All others are all weld metal tension tests.
- Optional diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label. (Also see A2.2 and A8.2 in the Annex.)

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. Specimens for retests may be taken from the original test assembly or from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet their requirement.

8. Weld Test Assemblies

8.1 At least one weld test assembly is required, and two may be required (depending on the electrode — solid as opposed to composite — and the manner in which the sample for chemical analysis is taken), as specified in Table 5. They are as follows:

(1) the groove weld in Fig. 1 for mechanical properties and soundness of the weld metal for both composite and solid electrodes, or the groove weld in Fig. 2 for mechanical properties of composite stranded and composite metal cored electrodes designated for single-pass applications only

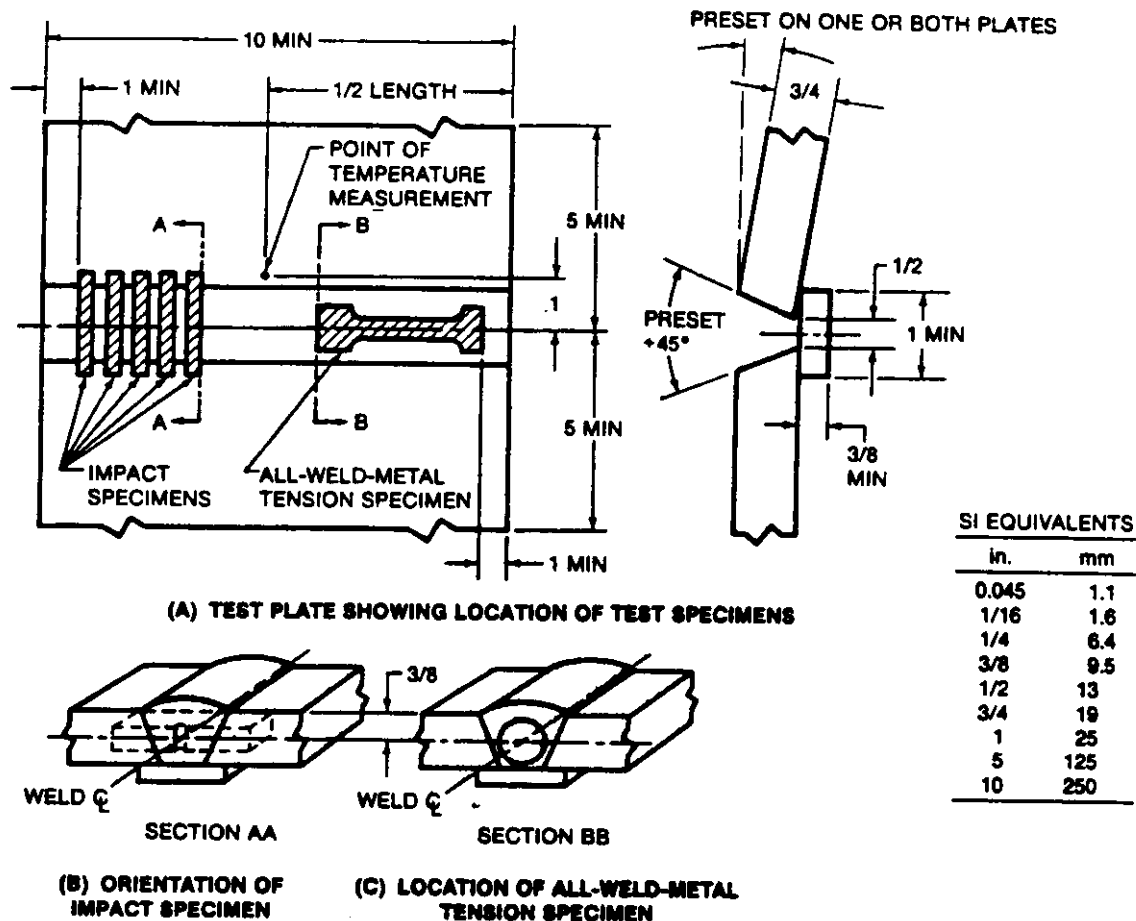
(2) the weld pad in Fig. 3 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes.

The sample for chemical analysis of weld metal from composite electrodes may be taken from the reduced section of the fractured all-weld-metal tension test specimen or from the corresponding location in the groove weld in Fig. 1, thereby avoiding the need to make a weld pad. Alternatively, the sample from the groove weld in Fig. 1 may be taken from any location in the weld metal above the tension test specimen. In case of dispute, the weld pad in Fig. 3 shall be the referee method.

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3, 8.4, and 8.5. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the ASTM specification shown there, or an equivalent specification. Testing of the assembly shall be as prescribed in 9.2, 9.3, and Sections 10 through 13.

8.3 Groove Weld

8.3.1 For all classifications except E70C-GS(X), a test assembly shall be prepared and welded as specified in Fig. 1, using base metal of the appropriate type specified in Table 6. The electrode used shall be 0.045 in. (1.1 mm) or $\frac{1}{16}$ in. (1.6 mm) size (or the size the

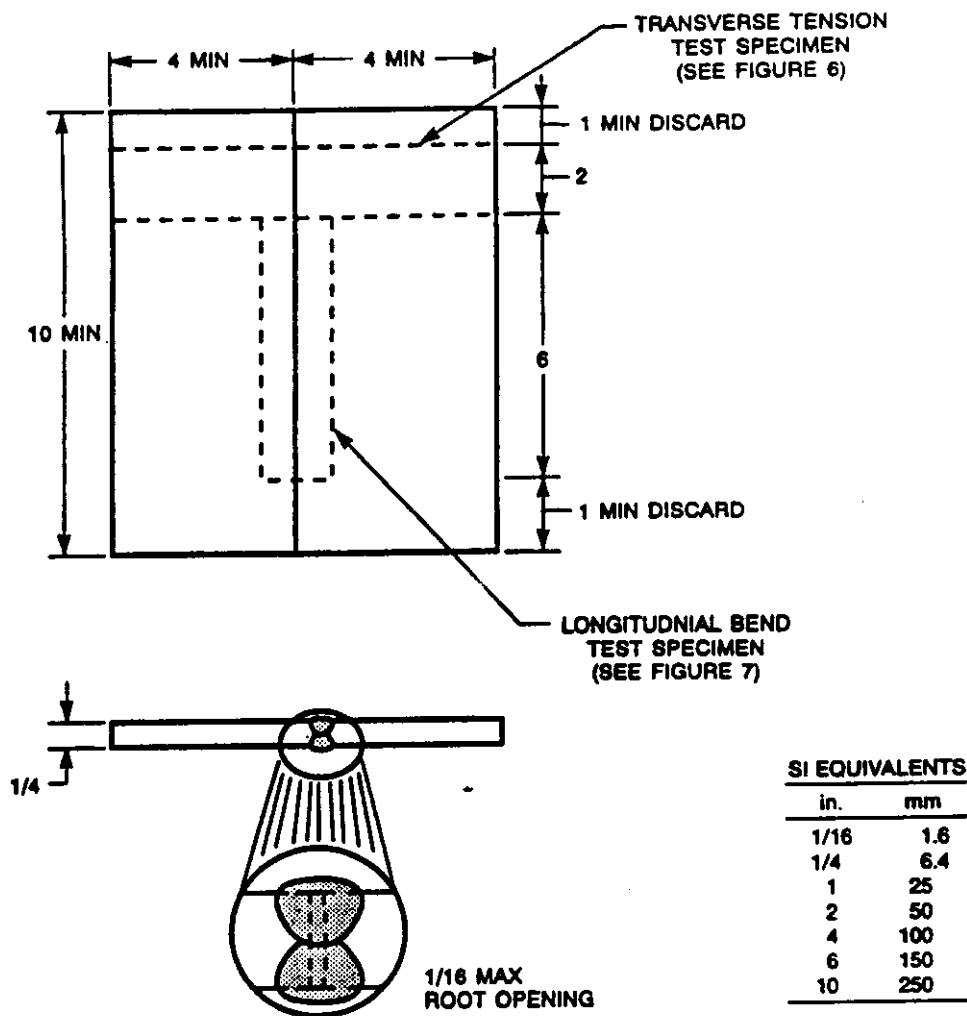
Test Conditions for Solid Electrodes^{c,d}

Standard size ^a	0.045 in.	1/16 in.
Shielding gas ^f	CO ₂	CO ₂
Wire feed speed	450 in./min (190 mm/sec) $\pm$ 5%	240 in./min (102 mm/sec) $\pm$ 5%
Nominal arc voltage	27 to 31 V	26 to 30 V
Resulting current, DCEP ^e (DCEP = electrode positive)	260 to 290 A	330 to 360 A
Tip-to-work distance ^h	3/4 $\pm$ 1/8 in. (19 $\pm$ 3 mm)	3/4 $\pm$ 1/8 in. (19 $\pm$ 3 mm)
Travel speed	13 $\pm$ 1 in./min (5.5 $\pm$ 0.5 mm/sec)	13 $\pm$ 1 in./min (5.5 $\pm$ 0.5 mm/sec)

Notes:

- All dimensions (excluding angles) are in inches.
- Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.
- Test conditions for composite electrodes shall be as recommended by the manufacturer.
- Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in 8.3.1.
- If sizes other than 0.045 in. and 1/16 in. are tested, wire feed speed, (and resulting current), arc voltage, and tip-to-work distance shall be changed as needed. This joint configuration is not recommended for electrode sizes smaller than 0.035 in. (0.9 mm).
- If shielding gases or blends other than CO₂ are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.
- The required combinations of electrode feed rate, arc voltage, and tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, tip-to-work distance, voltage settings, or in instrumentation.
- Distance from the contact tip to the work, not from the shielding gas cup to the work.

FIG. 1 GROOVE WELD TEST ASSEMBLY FOR MECHANICAL PROPERTIES AND SOUNDNESS



- Notes:
- All dimensions are in inches.
 - Detail A shows the completed joint and approximate weld configuration.

FIG. 2 GROOVE WELD TEST ASSEMBLY FOR TRANSVERSE TENSION AND LONGITUDINAL GUIDED BEND TESTS

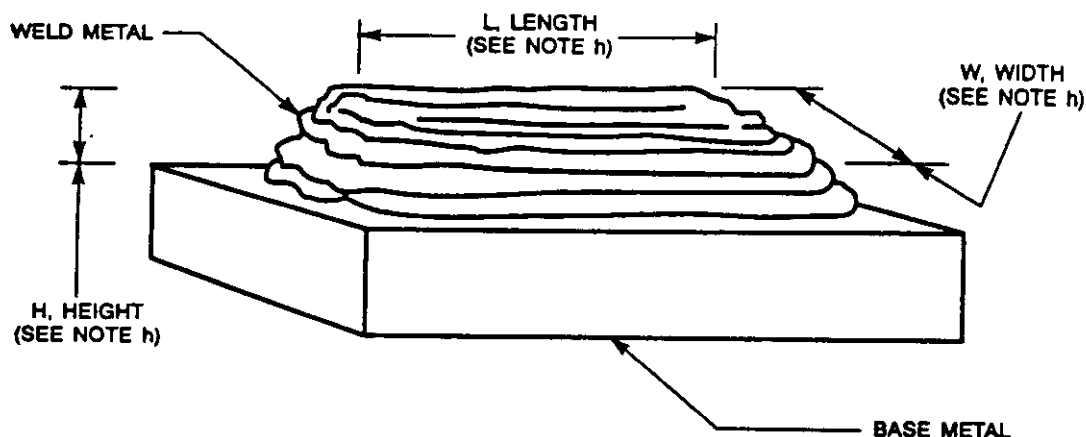
manufacturer produces that is closest to one of these, if these sizes are not produced).

Welding shall be in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5 deg. An assembly that is warped more than 5 deg. shall be discarded. It shall not be straightened. The test assembly shall be tack welded at room temperature and welding shall begin at that temperature [60°F (16°C) minimum]. Welding shall continue until the assembly has reached a maximum interpass temperature of 325°F (164°C), measured by

temperature indicating crayons or surface thermometers at the location shown in Fig. 1.

For the remainder of the weld, a minimum preheat temperature of 275°F (136°C) and maximum interpass temperature of 325°F (164°C) shall be maintained. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be preheated to a temperature of 300 ± 25°F (150 ± 14°C) before welding is resumed.

When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested

**Notes:**

- a. Base metal of any convenient size, of any type specified in Table 6, shall be used as the base for the weld pad.
- b. The surface of the base metal on which the filler metal is to be deposited shall be clean.
- c. The pad shall be welded in the flat position with successive layers to obtain weld metal of sufficient height.
- d. The number and size of the beads will vary according to the size of the electrode and the width of the weave, as well as the amperage employed.
- e. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed 325°F (164°C).
- f. Any slag shall be removed after each pass.
- g. The test assembly may be quenched in water between passes to control interpass temperature.
- h. The minimum completed pad size shall be at least four layers in height (H), length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis. The sample for analysis shall be taken at least 3/8 in. (9.5 mm) above the original base metal surface.

FIG. 3 PAD FOR CHEMICAL ANALYSIS OF WELD METAL FROM COMPOSITE ELECTRODES

TABLE 6
BASE METAL FOR TEST ASSEMBLIES

AWS Classification	ASTM Specification	UNS Number
All except E70C-GS(X)	A36,	K02600
	A285 Grade C,	K02801
	A515 Grade 70 or	K03101
	A516 Grade 70	K02700
E70C-GS(X)	A515 Grade 70 or	K03101
	A516 Grade 70	K02700

as specified in Section 10, Radiographic Test; Section 11, Tension Test; and Section 13, Impact Test. All testing will be performed in the as-welded condition except for the optional aging of the all-weld-metal tension test specimen specified in 11.1.1.

8.3.2 For single-pass electrodes [classification E70C-GS(X)] a test assembly using a base metal as

specified in Table 6 shall be prepared and welded as shown in Fig. 2. After tack welding the plates at each end, the test assembly shall be welded in the flat position, with one bead on each side. Welding shall begin with the assembly at room temperature [60°F (16°C) minimum]. When the weld bead has been completed on one side the assembly shall be turned over and the bead deposited on that side, as shown in Fig. 2. This sequence shall not be interrupted. The electrode size shall be 0.045 in. (1.1 mm) or 1/16 in. (1.6 mm) (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced).

After welding has been completed and the assembly has cooled in still air at room temperature, the assembly shall be prepared and tested as specified in 11.2 and Section 12, Bend Test. All testing will be performed in the as-welded condition except for the optional aging of the bend test specimen specified in 12.2

8.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes as shown in Fig. 3, except when, as permitted

in 8.1, the sample for analysis is taken from the groove weld (Fig. 1) or the fractured all-weld-metal tension test specimen. Base metal of any convenient size which will satisfy the minimum requirements of Fig. 3, and is of a type specified in Table 6, shall be used for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (4 layers minimum thickness). The electrode size shall be 0.045 in. (1.1 mm) or $1/16$ in. (1.6 mm) or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed 325°F (164°C). Any slag shall be removed after each pass. The pad may be quenched in water between passes (temperature of the water not specified). The dimensions of the completed pad shall be as shown in Fig. 3. Testing of this assembly shall be as specified in 9.2 and 9.3. The results shall meet the requirements of 9.4.

9. Chemical Analysis

9.1 A sample of the solid electrode or rod shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed, if its presence affects the results of the analysis for the other elements.

9.2 Composite stranded or metal cored electrodes shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the electrode and a shielding gas as specified in Tables 2 and 3. The sample may be taken from the weld pad prepared in accordance with 8.4, from an area of the groove weld as specified in 8.1, or from the reduced section of the fractured tension test specimen. In case of dispute, the weld pad is the referee method.

The top surface of the pad described in 8.4 and shown in Fig. 3 shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal, no closer than $3/8$ in. (9.5 mm) to the surface of the base metal in Fig. 3, by any appropriate mechanical means. The sample shall be free of slag. When the sample is taken from the groove weld or the reduced section of the fractured tension test specimen, that material shall be prepared for analysis by any suitable mechanical means.

9.3 The sample obtained as specified in 9.1 or 9.2 shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350, *Standard Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*.

9.4 The results of the analysis shall meet the requirements of Table 1 for solid electrode or Table 2 for composite electrodes for the classification of electrode under test.

10. Radiographic Test

10.1 The groove weld described in 8.3.1 and shown in Fig. 1 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

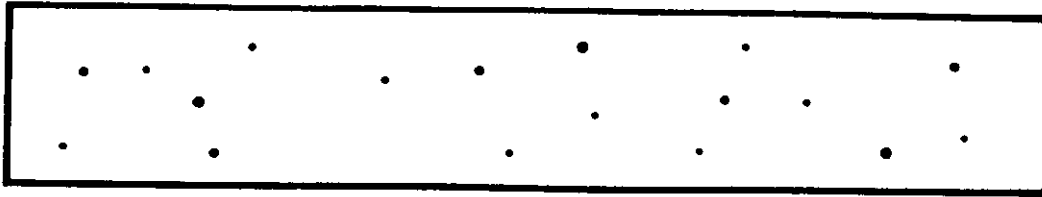
10.2 The weld shall be radiographed in accordance with ASTM E142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Fig. 4. In evaluating the radiograph, 1 in. (25 mm) of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape and they may have tails. The size of the rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension does not exceed $1/64$ in. (0.4 mm) shall be disregarded. Test assemblies with indications larger than the largest indications permitted in the radiographic standards (Fig. 4) do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.3.1, and shown in Fig. 1, as required in Table 5. The dimensions of the specimen shall be as shown in Fig. 5.

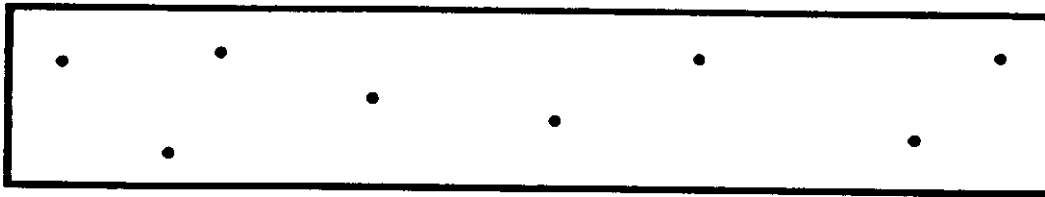
**(A) ASSORTED ROUNDED INDICATIONS**

SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:

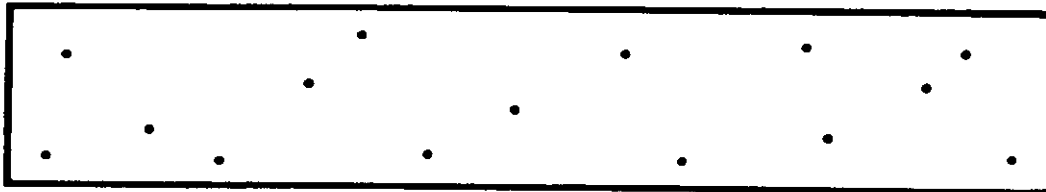
MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.

MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 5.

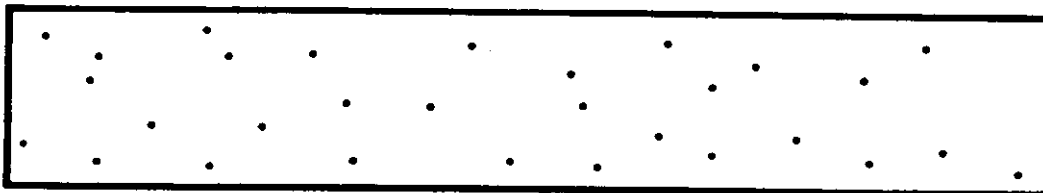
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 10.

**(B) LARGE ROUNDED INDICATIONS**

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 8.

**(C) MEDIUM ROUNDED INDICATIONS**

SIZE 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 15.

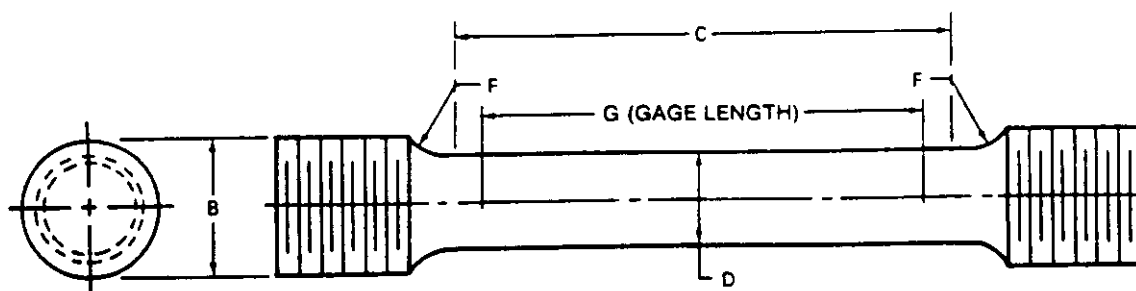
**(D) SMALL ROUNDED INDICATIONS**

SIZE 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH.
 MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 30.

Notes:

1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in. (0.4 mm) shall be disregarded.
4. These standards are equivalent to the Grade 1 standards of ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

FIG. 4 RADIOGRAPHIC ACCEPTANCE STANDARDS



Dimensions of Specimen, in.				
D	G	C	B	F, min.
0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375

Dimensions of Specimen, mm				
D	G	C	B	F, min.
12.7 ± 0.2	50.8 ± 0.1	57	19	9.5

Notes:

- Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
- The diameter of the specimen within the gage length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
- When the extensometer is required to determine yield strength, dimension C may be increased. However, the percent of the elongation shall be based on dimension G.
- The surface finish within the C dimension shall be no rougher than 63 μ in. (1.6 μ m).

FIG. 5 TENSION TEST SPECIMEN

11.1.1 After machining, but before testing, the specimen may be aged at 200 to 220°F (93 to 104°C) for up to 48 hr, then allowed to cool to room temperature.

11.1.2 The specimen shall be tested in the manner described in the tension test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 3.

11.2 One traverse tension test specimen shall be obtained from the groove weld described in 8.3.2, and shown in Fig. 2, as required in Table 5. The dimensions of the specimen shall be as shown in Fig. 6.

11.2.1 The specimen shall be tested in the as-welded (unaged) condition in the manner described in the tension test section of ANSI/AWS B4.0.

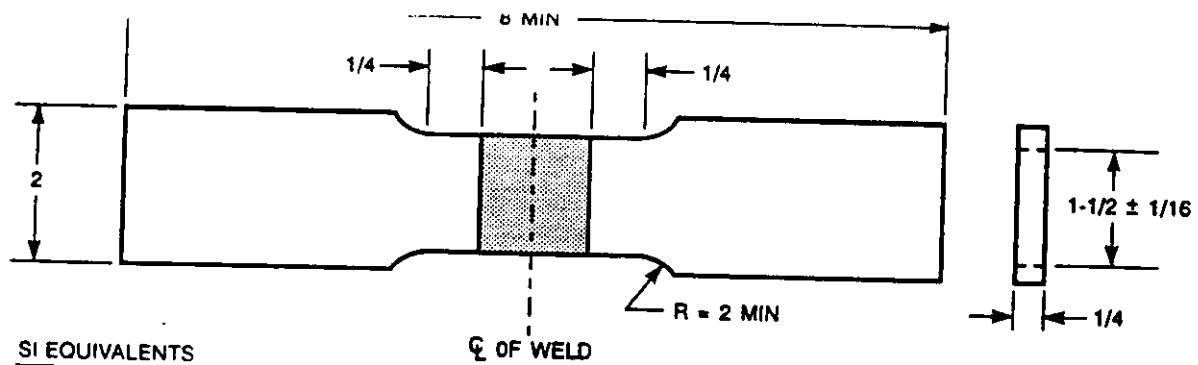
11.2.2 The results of the traverse tension test shall meet the requirements specified in Table 3. A test specimen that fractures in the base metal shall be considered to have met those requirements.

12. Bend Test

12.1 One longitudinal bend test specimen shall be machined from the groove weld test assembly described in 8.3.2, and shown in Fig. 2, as required in Table 5. The dimensions of the specimen shall be as shown in Fig. 7.

12.2 After machining, but before bending, the specimen may be aged at 200 to 220°F (93 to 104°C) for up to 48 hr, then allowed to cool to room temperature.

12.3 The specimen shall be tested in the manner described in the bend test section of ANSI/AWS B4.0, on any of the standard bend test jigs shown there. The



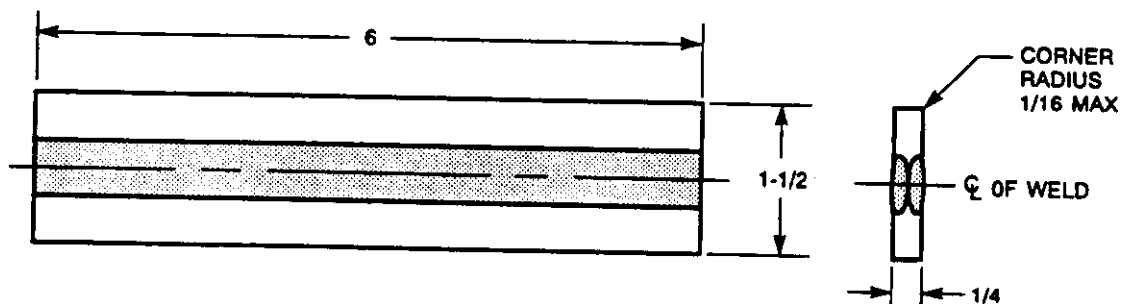
SI EQUIVALENTS

in.	mm
1/16	1.6
1/4	6.4
2	50
8	200
1-1/2	38

Notes:

- All dimensions are in inches.
- Weld reinforcement shall be ground or machined smooth and flush with the surfaces of the specimen. Grinding and machining marks shall be parallel to the length of the longest dimension of the specimen.

FIG. 6 TRANSVERSE TENSION TEST SPECIMEN



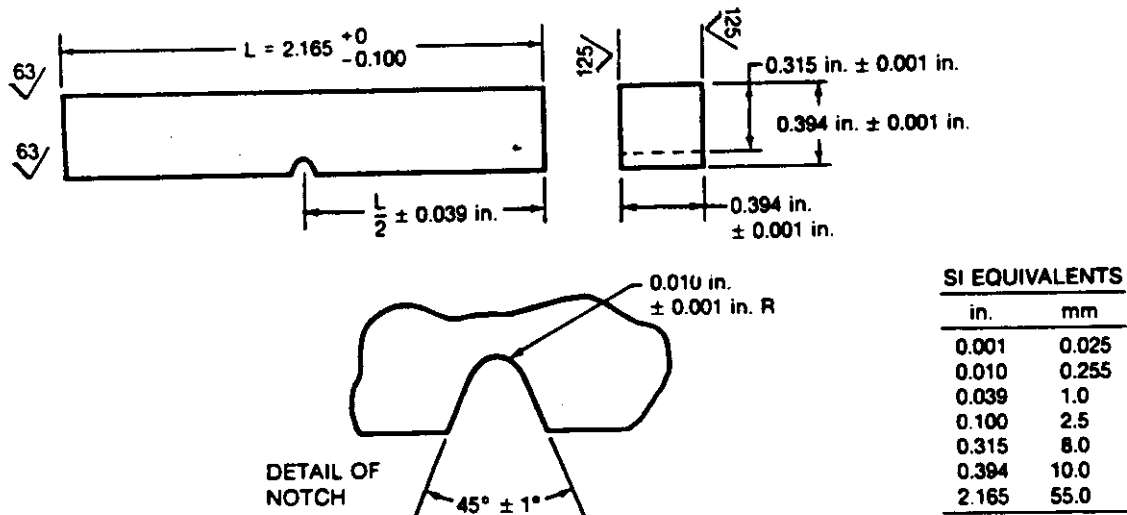
SI EQUIVALENTS

in.	mm
1/4	6.4
1-1/2	38
6	150

Notes:

- All dimensions are in inches.
- Weld reinforcement shall be ground or machined smooth and flush with the surfaces of the specimen. Grinding and machining marks shall be parallel to the length of the longest dimensions of the specimen.

FIG. 7 LONGITUDINAL GUIDED BEND TEST SPECIMEN



Notes:

1. The notched surface and the surface to be struck shall be parallel within 0.002 in. (0.05 mm) and have at least 63 μ in. (1.6 μ m) finish. The other two surfaces shall be square with the notched or struck surface within ± 10 minutes of the degree and have at least 125 μ in. (3.2 μ m) finish.
2. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.
3. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.
4. The correct location of the notch shall be verified by etching before or after machining.
5. If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+).

FIG. 8 CHARPY V-NOTCH IMPACT TEST SPECIMEN

bend radius shall be $\frac{3}{4}$ in. (19 mm). Positioning of the specimen shall be such that the bead with the greater surface discontinuities, if any, is in tension.

12.4 After bending, each specimen shall conform to the $\frac{3}{4}$ in. (19 mm) radius, with appropriate allowance for springback, and the weld metal shall not contain openings in excess of $\frac{1}{8}$ in. (3.2 mm) on the convex surface.

13. Impact Test

13.1 Five Charpy V-notch impact test specimens (Fig. 8) shall be machined from the test assembly shown in Fig. 1, for those classifications for which impact testing is required in Table 5.

13.2 The five specimens shall be tested in accordance with the impact test section of ANSI/AWS B4.0. The

test temperature shall be that specified in Table 4 for the classification under test.

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified 20 ft·lbf (27 J) energy level. One of the three may be lower, but not lower than 15 ft·lbf (20 J), and the average of the three shall be not less than the required 20 ft·lbf (27 J) energy level.

13.4 For classifications with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft·lbf (102 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 (102 J).

TABLE 7
OPTIONAL DIFFUSIBLE HYDROGEN
REQUIREMENTS^a

AWS Classification	Optional Supplemental Diffusible Hydrogen Designator ^{a,b}	Average Diffusible Hydrogen, Maximum (ml/100g Deposited Metal) ^c
All	H16	16.0
All	H8	8.0
All	H4	4.0

NOTES:

- a. See Note c to Table 5.
 b. This designator is added to the end of the complete electrode classification designation.
 c. Some classifications may not meet the lower average diffusible hydrogen levels (H8 and H4).

14. Diffusible Hydrogen Test

14.1 For each electrode to be designated by an optional supplemental diffusible hydrogen designator, the 0.045 in. (1.1 mm) or $\frac{1}{16}$ in. (1.6 mm) size, or the size that the manufacturer produces that is closest to one of these sizes if the specified sizes are not produced, shall be tested according to one of the methods given in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. The optional supplemental diffusible hydrogen designator may be added to the classification according to the average test value as compared to the requirements of Table 7. If the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator as specified in Table 7, the electrode also meets the requirements for all higher hydrogen designators in Table 7 without the need for retest.

14.2 Testing shall be done without rebaking or otherwise conditioning the electrode, unless the manufacturer recommends otherwise. If the electrode is rebaked, that fact, along with the method used for rebaking, shall be noted on the test report.

14.3 For purposes of certifying compliance with optional diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapor per pound (1.43 g/kg) of dry air at the time of welding. The actual atmospheric

conditions shall be reported, along with the average value for the test, according to ANSI/AWS A4.3.⁵

14.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable optional supplemental designator.

PART C — MANUFACTURE, IDENTIFICATION, AND PACKAGING

15. Method of Manufacture

The 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.

16. Standard Sizes

Standard sizes for electrodes and rods in the different package forms (straight lengths, coils with support, coils without support, drums and spools — see Section 18, Standard Package Forms) are as shown in Table 8.

17. Finish and Uniformity

17.1 All electrodes and rods shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint in composite metal cored electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

17.2 Each continuous length of filler metal shall be from a single heat or lot 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.

17.3 The components in composite electrodes (including the core ingredients in metal cored electrodes) shall be distributed with sufficient uniformity throughout the length of the electrode so as not to adversely affect the performance of the electrode or the properties of the weld metal.

17.4 A suitable protective coating may be applied to any filler metal in this specification. Copper may

⁵ See A8.2 (in the Appendix).

PART C — SPECIFICATIONS FOR WELDING RODS,
ELECTRODES, AND FILLER METALS

SFA-5.18

TABLE 8
STANDARD SIZES^a

Standard Package Form	Diameter		Tolerance (±)			
			Solid		Composite	
			in.	mm	in.	mm
Straight Lengths ^b			0.045	1.1	0.001	0.02
			0.062	1.6	0.002	0.05
	1/16		0.078	2.0	0.002	0.05
	5/64		0.094	2.4	0.002	0.05
	3/32		0.125	3.2	0.002	0.05
	1/8		0.156	4.0	0.002	0.05
	5/32		0.188	4.8	0.002	0.05
Coils With and Without Support			0.030	0.8	0.001	0.02
			0.035	0.9	0.001	0.02
			0.045	1.1	0.001	0.02
			0.052	1.3	0.002	0.05
	1/16		0.062	1.6	0.002	0.05
	5/64		0.078	2.0	0.002	0.05
	3/32		0.094	2.4	0.002	0.05
	7/64		0.109	2.8	0.002	0.05
	1/8		0.125	3.2	0.002	0.05
			0.035	0.9	0.001	0.02
Drums			0.045	1.1	0.001	0.02
			0.052	1.3	0.002	0.05
	1/16		0.062	1.6	0.002	0.05
	5/64		0.078	2.0	0.002	0.05
	3/32		0.094	2.4	0.002	0.05
	7/64		0.109	2.8	0.002	0.05
	1/8		0.125	3.2	0.002	0.05
			0.020	0.5	0.001	0.02
			0.025	0.6	0.001	0.02
			0.030	0.8	0.001	0.02
Spools			0.035	0.9	0.001	0.02
			0.045	1.1	0.001	0.02
			0.052	1.3	0.002	0.05
	1/16		0.062	1.6	0.002	0.05
	5/16		0.078	2.0	0.002	0.05
	3/32		0.094	2.4	0.002	0.05
	7/64		0.109	2.8	0.002	0.05
			0.020	0.5	0.001	0.02
			0.025	0.6	0.001	0.02
			0.030	0.8	0.001	0.02

NOTES:

- Dimensions, sizes, tolerances and package forms other than those shown shall be as agreed by purchaser and supplier.
- Length shall be 36 in. ± 1/2 in. (approximately 900 mm, ±15 mm).

TABLE 9
PACKAGING REQUIREMENTS^a

Type of Package	Package Size			Net Weight of Electrode		
	in.		mm	lb	kg. (approx.)	
Coils without Support	As specified by purchaser ^c			As specified by purchaser ^c		
Coils with Support (See below)	6- ³ / ₄	ID	170	14	6.4	
	12	ID	300	25, 30, 50, 60, and 65	11, 14, 23, 27, and 30	
Spools	4	OD	100	1½ and 2½	0.7 and 1.1	
	8	OD	200	10, 12, and 15	4.5, 5.5, and 6.8	
	12	OD	300	25, 30, 35, and 44	11, 14, 16, and 20	
	14	OD	360	50 and 60	23 and 27	
	22	OD	560	250	110	
	24	OD	610	300	140	
	30	OD	760	600, 750, and 1000	270, 340, and 454	
	Drums	15-½	OD	400	As specified by purchaser ^c	
20		OD	500	As specified by purchaser ^c		
23		OD	600	300 and 600	140 and 270	
Straight Lengths	36 long			10 and 60	4.5 and 22.7	
Coils with Support — Standard Dimensions and Weight						
Electrode Size	Coil Net Weight ^b		Coil Dimensions			
	lb	kg (approx.)	Inside Diameter of Liner		Width of Wound Electrode	
			in.	mm	in., max	mm, max
All	14	6.4	6¾ ± ⅛	170 ± 3	3	75
	25 and 30	11 and 14	12 ± ⅛	305 ± 3	2½ or 4⅝	65 or 120
	50, 60, and 65	23, 27, and 30	12 ± ⅛	305 ± 3	4⅝	120

NOTES:

- a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.
b. Tolerance on net weight shall be ±10 percent.
c. As agreed between supplier and purchaser.

be used as a coating for any classification except one that carries the suffix "N" (nuclear) in its designation.

18. Standard Package Forms

18.1 Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 9. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

18.2 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.

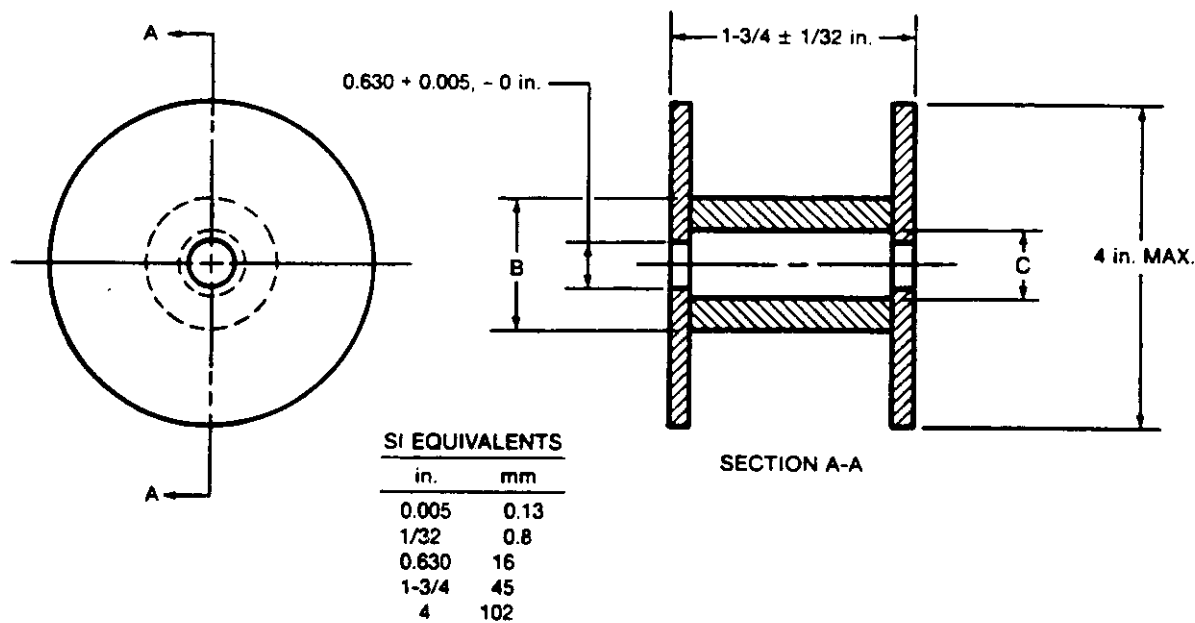
18.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough

to maintain the cleanliness of the filler metal. Standard spools are shown in Figs. 9A, 9B, and 9C.

19. Winding Requirements

19.1 Electrodes on spools and in coils (including drums and reels) 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 with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

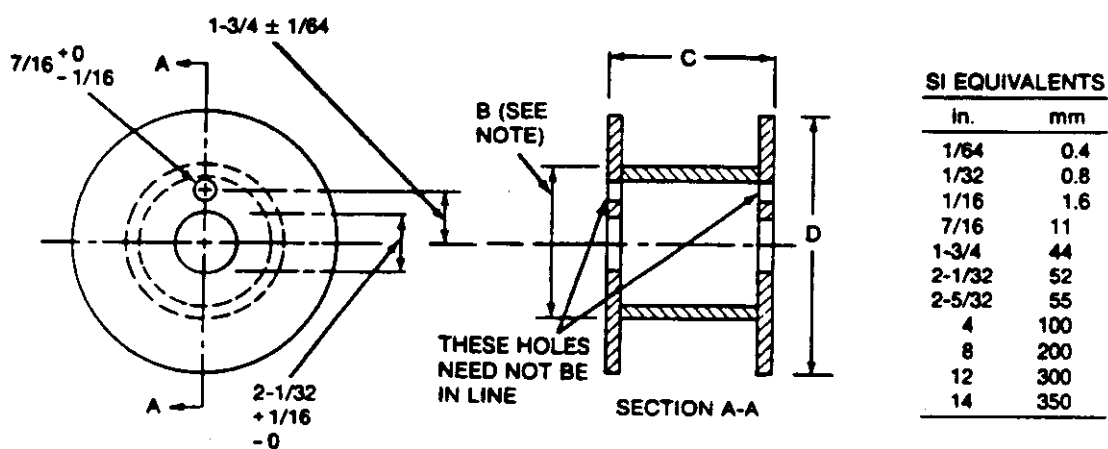
19.2 The cast and helix of electrode in coils, spools, and drums, shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.



Notes:

1. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.
2. Dimension C, inside diameter of barrel, shall be such that 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.

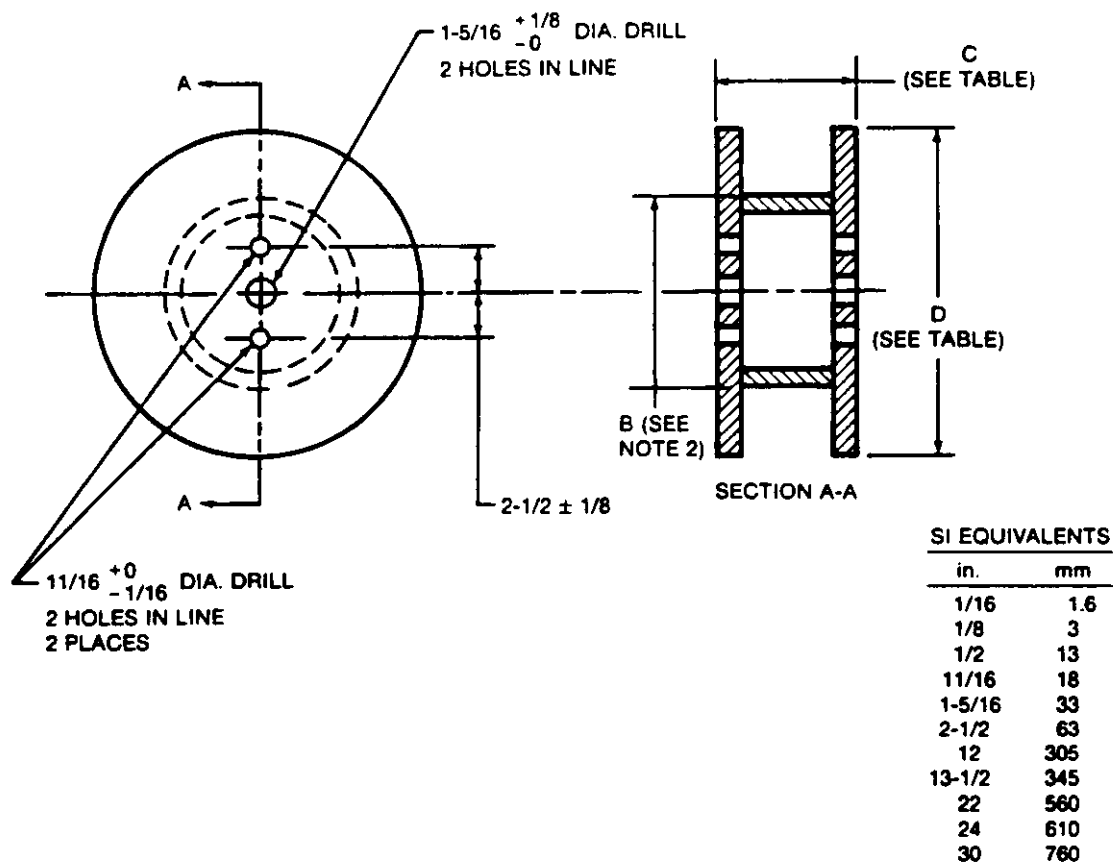
FIG. 9A STANDARD SPOOLS — DIMENSIONS OF 4 IN. SPOOLS



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

Dimensions		
Spool Size, in.	C, in.	D, maximum, in.
8	2-5/32 ± 1/32	8
12	4 ± 1/16	12
14	4 ± 1/16	14

FIG. 9B STANDARD SPOOLS — DIMENSIONS OF 8, 12, AND 14 IN. SPOOLS



Dimensions		
Spool Size, in.	D, in.	C, maximum, in.
22	$22 \pm 1/2$	12
24	$24 \pm 1/2$	13-1/2
30	$30 \pm 1/2$	13-1/2

Notes:

1. All dimensions are in inches.

2. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

FIG. 9C STANDARD SPOOLS — DIMENSIONS OF 22, 24, AND 30 IN. SPOOLS

19.3 The cast and helix of solid filler metal on 4 in. (100 mm) spools shall be such that the specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will

(1) form a circle not less than 4 in. (100 mm) nor more than 9 in. (230 mm) in diameter

(2) rise above the flat surface no more than $1/2$ in. (13 mm) at any location.

19.4 The cast and helix of solid filler metal on all other package forms shall be such that the specimen long enough to produce a single loop, when cut from the package and laid unrestrained on a flat surface, will

(1) form a circle not less than 12 in. (305 mm) for 0.030 in. (0.8 mm) and smaller sizes; or not less than 15 in. (380 mm) for 0.035 in. (0.9 mm) and larger sizes

(2) rise above the flat surface no more than 1 in. (25 mm) at any location.

Certain bulk packages may contain wire that has been elastically twisted or otherwise treated to provide straight wire feed. Wire from these packages will not form a circle when cut. Traditional cast and helix measurements may have no relevance. Wire thus treated shall conform only to the winding requirements of 19.1 and 19.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

20. Filler Metal Identification

20.1 The product information and the precautionary information required in Section 22 for marking each package shall also appear on each coil, spool, and drum.

20.2 Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

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

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

20.5 Drums shall have the information securely affixed in a prominent location on the side of the drum.

21. Packaging

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

22. Marking of Packages

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

- AWS specification (year of issue may be excluded) and AWS classification numbers, along with any optional supplemental designators, if applicable
- Supplier's name and trade designation
- Size and net weight
- Lot, control, or heat number

22.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of electrodes and rods, 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, 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 Classification of Carbon Steel Filler Metals for Gas Shielded Arc Welding

(This Appendix is not a part of ANSI/AWS A5.18-93, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for information only.)

A1. Introduction

A1.1 The purpose of this guide is to correlate the electrode and rod 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 electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications as shown in Fig. A1.

A2.2 The prefix "E" designates an electrode as in other specifications. The letters "ER" indicate that the filler metal may be used either as an electrode or a rod. The number 70 indicates the required minimum tensile strength as a multiple of 1000 psi (6.9 MPa) of the weld metal in a test weld made using the electrode in accordance with the welding conditions in the specification. The letter "S" designates a solid electrode or rod. The letter "C" designates a composite electrode. The digit following the hyphen, 2, 3, 4, 5, 6, 7, G, or GS, indicates the chemical composition of the filler metal itself, in the case of solid electrodes and rods, or the impact testing temperature of the weld metal under certain test conditions, in the case of the both solid and composite stranded and metal cored electrodes. In the case of some composite stranded and metal cored electrodes, the letter "M" or "C" will follow, indicating the type of shielding gas.

The addition of the letter "N" as a suffix to a classification indicates that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorous, vanadium, and copper contents of the weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal has a high upper shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years.

An optional supplemental diffusible hydrogen designator (H16, H8, or H4) may follow, indicating whether the electrode will meet a maximum hydrogen level of 16, 8, or 4 ml/100g of weld metal when tested as outlined in ANSI/AWS A4.3.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as ER70S-G, E70C-G, and E70C-GS. The "G" (multiple pass) or "GS" (single pass) 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 these classifications 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

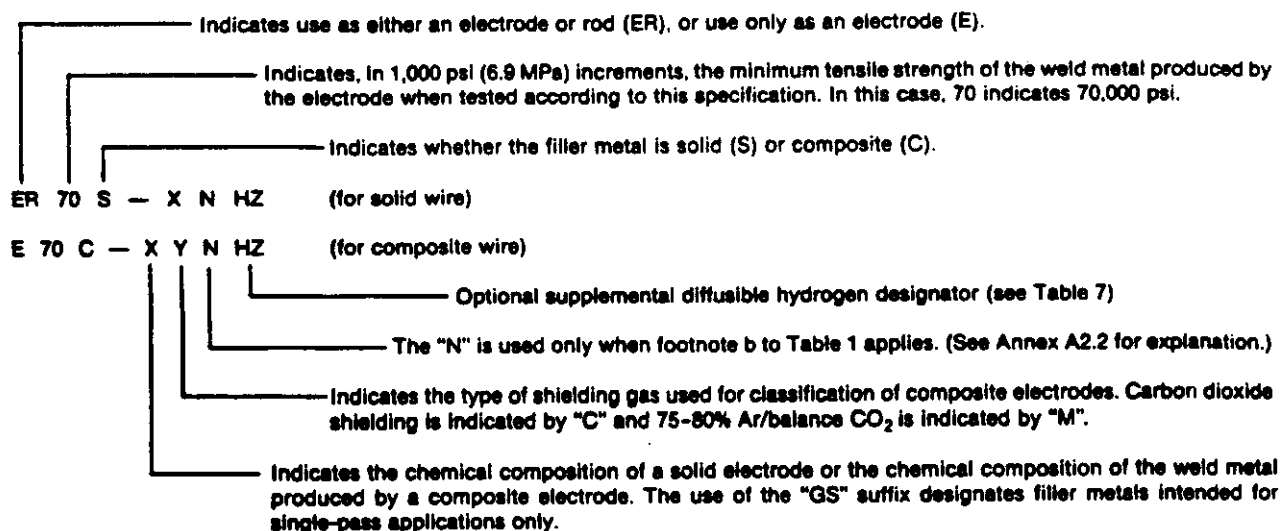


FIG. A1 CLASSIFICATION SYSTEM

existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some particular respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of the difference) referred to above will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

"Not Specified" is used in those areas of the specification that refer to the results of some particular test. It indicates that the requirements for that test are *not specified* for that particular classification.

"Not Required" is used in those areas of the specification that refer to the tests that must be conducted in order to classify a filler metal. It indicates that the test is *not required* because the requirements (results) for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test in order to consider a particular product of that classification for a certain application, they will have to arrange for that information with the supplier of the product. They will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. They may

want to incorporate that information (via ANSI/AWS A5.01) into the purchase order.

A2.3.3 Request for Filler Metal Classification

A2.3.3.1 When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. They may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Filler Metal Committee recommends that they still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

A2.3.3.2 A request to establish a new filler metal classification must be a written request and it needs to provide sufficient detail to permit the Filler Metal Committee or the subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

A2.3.3.3 The request should be sent to the Secretary of the Filler Metal Committee at AWS Headquarters. Upon receipt of the request, the Secretary will

(1) Assign an identifying number to the request. This number shall include the date the request was received.

(2) Confirm receipt of the request and give the identification number to the person who made the request.

(3) Send a copy of the request to the chairman of the Filler Metal Committee and the chairman of the particular subcommittee involved.

(4) File the original request.

(5) Add the request to the log of outstanding requests.

A2.3.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the secretary shall inform the requestor of the status of the request, with copies to the chairman of the committee and the subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the secretary shall report these to the chairman of the Filler Metal Committee for the chairman's actions.

A2.3.3.5 The secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each Filler Metal Committee meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

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, 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 that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. 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.

A4. Certification

A4.1 The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification identification 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 the certification is that the manufacturer has actually conducted the test 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 made. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in ANSI/AWS A5.01.

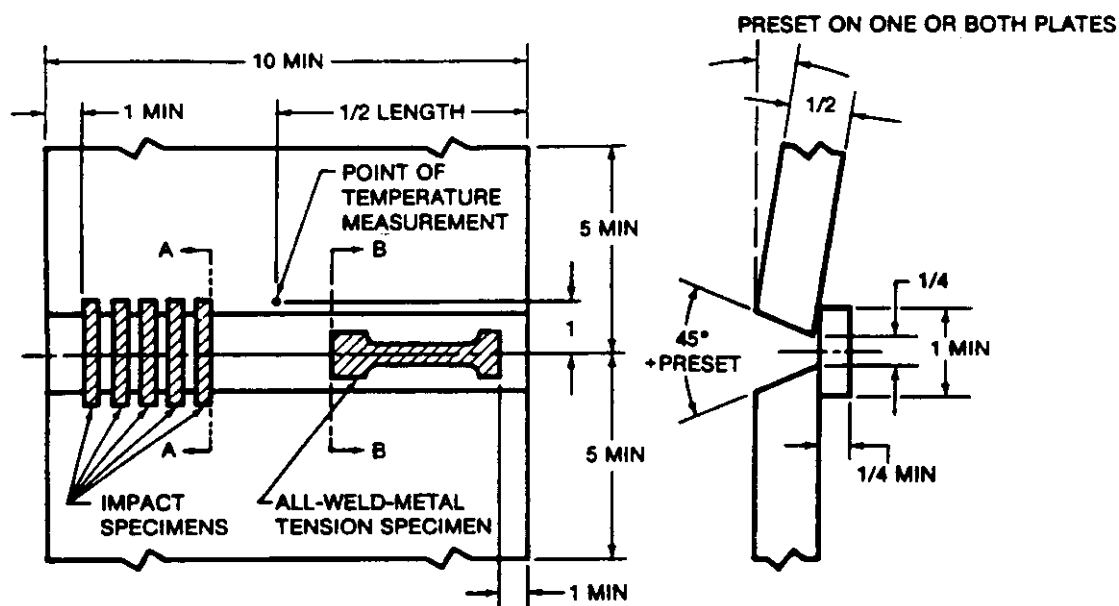
A4.2 (Optional) At the option and expense of the purchaser, acceptance may be based on the results of any or all of the tests required by this specification made on the GTAW test assembly described in Fig. A2, with the tension specimen as described in Fig. A3 (and the impact specimen described in Fig. 8). Composite electrodes are normally not recommended for GTAW or PAW.

A5. Ventilation During Welding

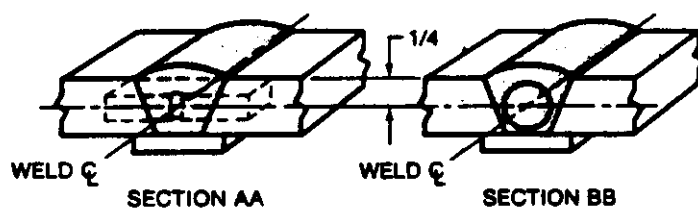
A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:

- (1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)
- (2) Number of welders or 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 particularly drawn to the section entitled "Ventilation."



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) ORIENTATION OF
IMPACT SPECIMEN

(C) LOCATION OF
ALL-WELD-METAL
TENSION SPECIMEN

SI EQUIVALENTS

in.	mm
1/4	6.4
1/2	12.7
1	25
5	125
10	250

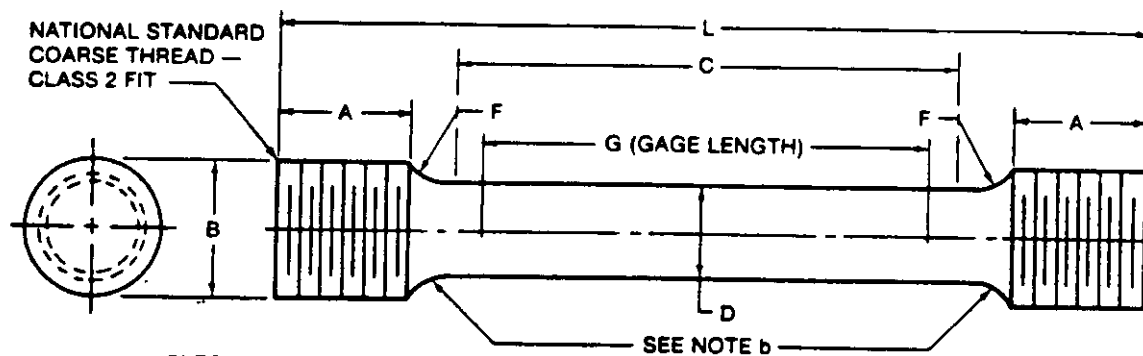
Test Conditions

Standard Size	3/32 in. (2.4 mm)	1/8 in. (3.2 mm)
Shielding Gas	Argon	Argon
Travel Speed	4 to 6 in./min (0.17 to 0.25 mm/sec)	4 to 6 in./min (0.17 to 0.25 mm/sec)
Nominal Arc Voltage	13 to 16 V	16 to 19 V
Nominal Current, DCEN (DCEN = electrode negative)	220 to 250 A	250 to 260 A
Preheat Temperature	275°F (136°C) min.	275°F (135°C) min.
Interpass Temperature	325°F (164°C) max.	325°F (164°C) max.

Notes:

- All dimensions (excluding angles) are in inches.
- Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.
- If sizes other than those shown above are used, nominal current and arc voltage shall be changed as needed.

FIG. A2 OPTIONAL GTAW GROOVE TEST WELD ASSEMBLY FOR MECHANICAL PROPERTIES AND
SOUNDNESS



SI EQUIVALENTS

in.	mm
0.005	0.13
0.007	0.18
0.25	6.4
0.350	8.90
1/2	12.7
1.400	35.5
1-3/4	44.0

Dimensions of Specimen, in.

D	G	C	B	F, min.
0.350 ± 0.007	1.400 ± 0.005	1-3/4	1/2	0.25

Notes:

- Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
- The diameter of the specimen within the gauge length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
- When the extensometer is required to determine yield strength, dimension C may be increased. However, the percent of the elongation shall be based on dimension G.
- The surface finish within the C dimension shall be no rougher than 64 μ in. (1.6 μ m).

FIG. A3 OPTIONAL TENSION TEST SPECIMEN FOR GAS TUNGSTEN ARC WELDING

A6. Welding Considerations

A6.1 Gas metal arc welding can be divided into three categories based on the mode of metal transfer employed. These modes are (1) spray (conventional or pulsed), (2) globular, and (3) 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 is deposited during frequent short circuiting of the electrode in the molten pool.

A6.2 Spray Transfer

A6.2.1 The spray transfer mode, for carbon steel, is most commonly obtained with argon shielding gas mixture with up to 5% of oxygen or 15% carbon

dioxide. A characteristic of this shielding gas is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

A6.2.2 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 of electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode at a rate 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 arc 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, 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 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. (1.1 and 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 1.1 mm)] using lower 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 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 alone. The penetration of such welds is greater with CO₂ than it is with argon-CO₂ mixtures. Mixtures of 50 to 80% argon (remainder CO₂) can be advantageous for thin material. They provide low penetration, higher short circuiting rates, and lower minimum currents and voltages than CO₂ alone does. This can be an advantage in welding thin plate.

A7. Description and Intended Use of Electrodes and Rods

A7.1 ER70S-2. Electrodes and rods of the ER70S-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. 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.

A7.2 ER70S-3. Electrodes and rods of the ER70S-3 classification are intended for welding single-pass and multiple-pass welds. Typical base metal specifications are often the same as those for the ER70S-2 classification.

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

A7.4 ER70S-5. Electrodes and rods of the ER70S-5 classification are intended for welding steel with CO₂ shielding and high welding currents. They can be used for steels with a slightly rusty surface, with perhaps some sacrifice of weld quality, depending on the condition of the surface. Typical base metal specifications are often the same as those for the ER70S-2 classification. This classification does not require impact testing.

A7.5 ER70S-6. Electrodes and rods of the ER70S-6 classification are intended for both single- and multiple-pass welding. They are 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. These electrodes withstand high currents with CO₂ shielding, even when welding rimmed steels. Typical base metal specifications are often the same as those for the ER70S-2 classification.

A7.6 ER70S-7. Electrodes and rods of the ER70S-7 classification are intended for single- and multiple-pass welding. They may permit welding with higher travel speeds compared with ER70S-3 filler metals. They also provide somewhat better wetting action and bead appearance when compared with those filler metals. Typical base metal specifications are often the same as those for the ER70S-2 classification.

A7.7 ER70S-G and E70C-G. Electrodes and rods of the ER70S-G and electrodes of the E70C-G classification are those filler metals not included in the preceding classes and for which only certain mechanical property requirements are specified. The electrodes are

intended for both single- and multi-pass applications. The filler metal supplier should be consulted for the composition, properties, characteristics, and intended use of these classifications (see A2.3 for further information).

A7.8 E70C-GS. Electrodes of the E70C-GS classification are composite stranded or metal cored electrodes intended for only single-pass applications. The electrodes may be classified with either CO₂ or 75–80% Ar/balance CO₂ as shown by the “C” or “M” suffix. Absence of the C or M suffix means that the shielding gas is not specified. The filler metal supplier should be consulted for the properties, characteristics, and intended use of these classifications. These electrodes may have higher alloy contents which improve single-pass applications (such as tolerance to mill scale, etc.) but could preclude their use on multiple-pass applications due to higher alloy recovery.

A7.9 E70C-3 and E70C-6. Electrodes of the E70C-3 and E70C-6 classifications are composite stranded or metal cored electrodes intended for both single- and multiple-pass applications. They are characterized by a spray arc and excellent bead wash characteristics. The electrodes may be classified with either CO₂ or 75–80% Ar/balance CO₂ as shown by the “C” or “M” suffix. Classification E70C-3 requires impacts at 0°F (–18°C) while E70C-6 requires impacts at –20°F (–29°C).

A8. Special Tests

A8.1 It is recognized that supplementary tests may be required to determine the suitability of these filler metals for certain applications involving properties not considered in this specification. In such cases, additional tests to determine specific properties of the weld metal, such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, may be required. These tests may be conducted as agreed between supplier and purchaser. ANSI/AWS A5.01 contains provisions for ordering such tests.

A8.2 Diffusible Hydrogen. Solid, composite stranded, and composite metal cored GMAW electrodes are generally considered to be low-hydrogen consumables. When joining carbon steels containing 0.30% or less carbon (such as those listed in Table 6), hydrogen assisted cracking is unlikely to be of concern with the electrodes of this specification. However, it is also likely that these electrodes will see service in joining carbon steel to low alloy, high-strength steels in which weld metal or heat-affected zone cracking associated

with diffusible hydrogen tends to become more of a problem with increasing weld metal strength, increasing heat-affected zone hardness, increasing diffusible hydrogen content, decreasing preheat and interpass temperature, and decreasing time at or above the interpass temperature during and after welding. This cracking is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-assisted cracking, it may be desirable to measure the diffusible hydrogen content resulting from a particular electrode. Accordingly, the use of optional supplemental designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 7, are also understood to meet any higher electrode hydrogen limits, even though these are not necessarily designated along with the electrode classification. Therefore, for example an electrode designated as “H4” also meets the “H8” and “H16” requirements without being designated as such.

The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

The use of a reference atmospheric condition during welding is necessary because the arc is always imperfectly shielded. Moisture from the air, distinct from that in the electrode or gas, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. The effect can be minimized by maintaining a suitable gas flow rate and as short an arc length as possible consistent with a steady arc. At times, some air will mix with the gas and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per pound (1.43 grams per kilogram) of dry air is equivalent to 10% relative humidity at 70°F (21°C) at 29.92 in. Hg (760 mm) barometric pressure. Actual conditions, measured using a calibrated psychrometer, that equal or exceed this reference condition provide assurance

that the conditions during welding will not diminish the final results of the test.

A9. Discontinued Classifications

The following classifications have been discontinued over the life of this specification:

Discontinued Classification	Last Published	Discontinued Classification	Last Published
E-60S-1	1965	E70S-1	1969
E-60S-2	1965	E70S-1B ^b	1969
E-60S-3	1965	E70S-2 ^c	1969
E-70T-1 ^a	1965	E70S-3 ^c	1969
E-70T-2 ^a	1965	E70S-4 ^c	1969
E-70T-3 ^a	1965	E70S-5 ^c	1969
E-70T-4 ^a	1965	E70S-6 ^c	1969
E-70T-5 ^a	1965	E70S-G ^c	1969
E-70T-G ^a	1965	E70U-1	1969

NOTES:

- These flux-cored electrode classifications were transferred to AWS A5.20-69 and continue to be included in the revisions to that specification.
- This electrode classification was transferred to the new AWS A5.28 specification where it is classified as ER80S-D2.
- These electrode classifications were changed to the new classification ER70S-X and remain in the current revision of the specification as such.

A10. Safety Information

A10.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn in combination with goggles or equivalent to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves,

leggings, and shoulder covers with bibs designed for welding service should be used.

Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph.

Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (*Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*)

The following sources are for more detailed information on personal protection:

(1) American National Standards Institute. ANSI/ASC Z41.1, *Safety-Toe Footwear*. New York: American National Standards Institute.⁶

(2) ANSI/ASC Z49.1, *Safety in Welding and Cutting*, Miami, FL: American Welding Society.

(3) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, New York: American National Standards Institute.

(4) Occupational Safety and Health Administration. *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910. Washington, DC: U.S. Government Printing Office.⁷

A10.2 Electrical Hazards. Electric shock can kill; however, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

⁶ ANSI documents are available from the American National Standards Institute, 11 West 42 Street, New York, NY 10036.

⁷ OSHA documents are available from U.S. Government Printing Office, Washington, DC 20402.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding and Cutting*, and NFPA No. 70, *National Electrical Code*,⁸ should be followed.

A10.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition

of the filler metal and base metal, welding process, flux, current level, arc length, and other factors.

The possible effects of over-exposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc or flame, or both, should be used to keep fumes and gases from your breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(1) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29, Chapter XVII, Part 1910.

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*.⁹

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*, available from the American Welding Society.

(4) Manufacturer's Material Safety Data Sheet for the product.

A10.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as X-rays), or non-ionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A10.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is

⁸ Available from the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

⁹ Published by the American Conference of Governmental Industrial Hygienists (ACGIH), 6550 Glenway Avenue, Building D-5, Cincinnati, OH 45211.

ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A10.4.2 Non-Ionizing Radiation. The intensity and wavelengths of non-ionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of non-ionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by non-ionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect a passerby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by American Welding Society.

(3) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. (Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)

(4) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(5) Safety glasses with UV protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

A10.4.3 Ionizing radiation information sources include the following:

(1) AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society.

(2) Manufacturer's product information literature.

A10.4.4 Non-ionizing radiation information sources include:

(1) American National Standards Institute. ANSI/ASC Z136.1, *Safe use of lasers*, New York, NY: American National Standards Institute.

(2) ANSI/ASC Z87.1, *Practice for occupational and educational eye and face protection*. New York, NY: American National Standards Institute.

(3) ANSI/ASC Z49.1, *Safety in Welding and Cutting*. (Published by AWS) Miami, FL: American Welding Society.

(4) Hinrichs, J. F., "Project Committee on Radiation—Summary report," *Welding Journal*, January, 1978.

(5) Moss, C. E. "Optical Radiation Transmission Levels Through Transparent Welding Curtains," *Welding Journal*, March 1979.

(6) Moss, C. E. and Murray, W. E., "Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting," *Welding Journal*, September 1979.

(7) Marshall, W. J., Sliney, D. H., and others. "Optical radiation levels produced by air-carbon arc cutting processes," *Welding Journal*, March 1980.

(8) National Technical Information Service. Non-ionizing radiation protection special study no. 42-0053-77, "Evaluation of the potential hazards from actinic ultraviolet radiation generated by electric welding and cutting arcs." Springfield, VA: National Technical Information Service, ADA-033768.

(9) Non-ionizing radiation protection special study no. 42-0312-77, "Evaluation of the potential retina hazards from optical radiation generated by electrical welding and cutting arcs." Springfield, VA: National Technical Information Service, ADA-043023.

