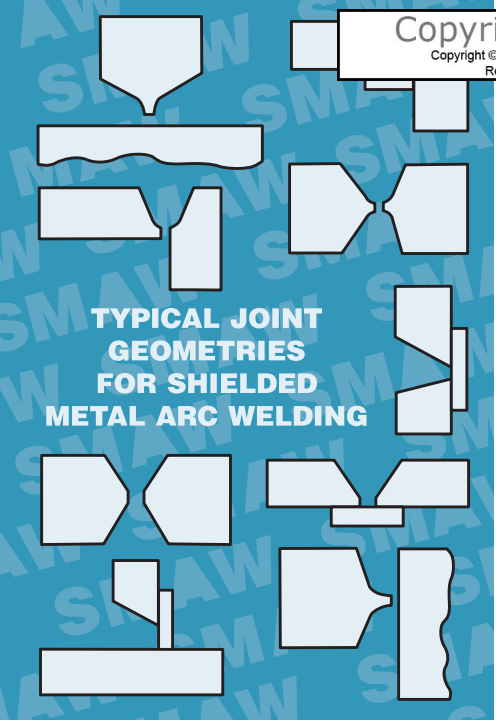


The Everyday Pocket Handbook for Shielded Metal Arc Welding (SMAW)

Number 7 in a series

Compiled as a useful tool for on-the-job welding personnel by the AWS Product Development Committee

Printed in the United States of America

American Welding Society

NOTE: Although care was taken in choosing and presenting the data in this guide, AWS cannot guarantee that it is error free. Further, this guide is not intended to be an exhaustive treatment of the topic and therefore may not include all available information, including with respect to safety and health issues. By publishing this guide, AWS does not insure anyone using the information it contains against any liability or injury to property or persons arising from that use.

Table of Contents

Basic Safety Precautions

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.

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 workpiece 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.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

Refer to AWS/ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, for additional information.

AWS Specifications for Covered Electrodes

Type of Electrode	AWS Specification
Carbon steel	A5.1
Low alloy steel	A5.5
Corrosion resistant steel	A5.4
Cast iron	A5.15
Aluminum and aluminum alloys	A5.3
Copper and copper alloys	A5.6
Nickel and nickel alloys	A5.11
Surfacing	A5.13 and A5.21

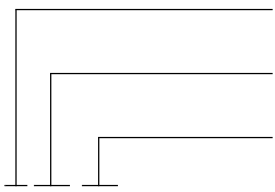
Engineering Functions of SMAW Electrode Coatings

• Promotes electrical conductivity by ionization of gases
• Produces shielding gas
• Adds slag formers for grain refinement
• Provides materials for controlling bead shape and width
• Provides alloy additions to deposit
• Concentrates arc stream
• Imparts characteristics for welding position
• Insulates core wire

Current Requirements for SMAW Electrode Classifications

Electrode Class	Current
EXX10	DCRP
EXX11	AC or DCRP
EXX13	AC or DC either polarity
EXX15	DCRP
EXX16	AC or DCRP
EXX18	AC or DCRP
EXX20	AC or DCSP (horizontal fillet) AC or DC either polarity (flat)
EXX27	AC or DCSP (horizontal fillet) AC or DC either polarity (flat)

Classification System for Carbon Steel Electrodes for SMAW



Designates an electrode. This designator may be deleted from the product imprint required for identification of the electrode.

Designates the tensile strength (minimum), in ksi, of the weld metal when produced in accordance with the test assembly preparation procedure of this specification.

Designates the welding position in which electrodes are usable, the type of covering, and the kind of welding current for which the electrodes are suitable.

Optional Supplemental Designators:

Designates that the electrode meets the requirements of the absorbed moisture test (an optional supplemental test for all low hydrogen electrodes except the E7018M classification, for which the test is required).

Designates that the electrode meets the requirements of the diffusible hydrogen test (an optional supplemental test of the weld metal from low hydrogen electrodes, as-received or conditioned — with an average value not exceeding "Z" mL of H_2 per 100g of deposited metal, where "Z" is 4, 8, or 16).

Designates that the electrode (E7016, E7018, or E7024) meets the requirements for improved toughness — and ductility in the case of E7024.

Interpretation of Last Digit in AWS Electrode Classification

Last Digit	0	1	2	3	4	5	6	7	8
Power supply	Note a	AC or DC reverse polarity	AC or DC	AC or DC	AC or DC	DC reverse polarity	AC or DC reverse polarity	AC or DC	AC or DC reverse polarity
Type of slag	Note b	Organic	Rutile	Rutile	Rutile	Low Hydrogen	Low Hydrogen	Mineral	Low Hydrogen
Type of arc penetration	Digging Note c	Digging Deep	Medium Medium	Soft Light	Soft Light	Medium Medium	Medium Medium	Soft Medium	Medium Medium
Iron powder in coating	0–10%	None	0–10%	0–10%	30–50%	None	None	50%	30–50%

a. E6010 is DC reverse polarity; E6020 is AC or DC.
b. E6010 is organic; E-6020 is mineral.
c. E6010 is deep penetration; E-6020 is medium penetration.

Meaning of Suffix in Classification of Carbon Steel and Low-Allow Steel SMAW Electrodes

Suffix	Meaning
A1	1/2% Molybdenum
B1	1/2% Chromium, 1/2% Molybdenum
B2	1-1/4% Chromium, 1/2% Molybdenum
B2L	Low Carbon version of B2 type (carbon content is 0.05% or less)
B3	2-1/4% Chromium, 1% Molybdenum
B3L	Low Carbon version of B3 type (carbon content is 0.05% or less)
B4L	2% Chromium, 1/2% Molybdenum, Low Carbon (0.05% or less)
B5	1/2% Chromium, 1.1% Molybdenum
C3	1% Nickel
C1	2% Nickel
C2	3% Nickel
D1	1-1/2% Manganese, 1/3% Molybdenum
D2	1-3/4% Manganese, 1/3% Molybdenum
M	Conforms to compositions covered by military specifications
G	Needs only a minimum of one of the elements listed in the AWS A5.5 table for chemical requirements

CLASS	AVERAGE EFFICIENCY*
E6010	63.8%
E6011	68.5%
E6012	66.9%
E6013	66.8%
E7014	64.6%
E7016	62.8%
E7018	69.5%
E6020	65.2%
E7024	66.8%
E7027	68.3%

STUB LOSS**		
STUB LENGTH	5/32 E6010 % DEPOSIT	14 in. % LOSS
2 in.	63.8	36.2
3 in.	58.5	41.5
4 in.	53.2	46.8
5 in.	47.9	52.1
6 in.	42.6	57.4

$$\text{EFFICIENCY} = \frac{\text{WEIGHT OF WELD METAL}}{\text{WEIGHT OF ELECTRODE USED, INCLUDING STUB}}$$

*INCLUDES 2 in. STUB LOSS.

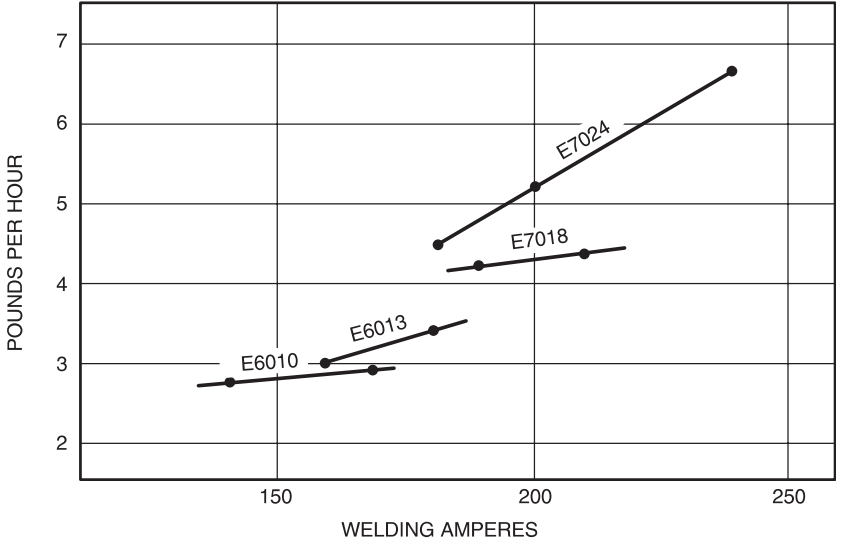
**E6010 IS 71.57% EFFICIENT, LOSS DUE TO SLAG, SPATTER, AND SMOKE.

Electrode Deposition Efficiency and Stub Loss Factors

Suggested Amperage Ranges for Carbon Steel and Low-Alloy Steel Electrodes

Electrode	Diameter (in.)	Amperage (A)
E6010 and E6011	3/32	50–70
	1/8	100–130
	5/32	140–170
	3/16	160–190
	7/32	190–230
E6012	1/8	100–130
	5/32	165–200
	3/16	220–240
	7/32	275–320
	1/4	320–380
E6013	3/32	60–75
	1/8	100–135
	5/32	140–180
	3/16	180–220
	7/32	250–290

Electrode	Diameter (in.)	Amperage (A)
E7018	3/32	70–110
	1/8	120–160
	5/32	150–200
	3/16	200–275
	7/32	250–340
E7024	1/8	140–180
	5/32	180–240
	3/16	245–290
	7/32	320–360
	1/4	400–450



Deposition Rate, 5/32 in. Diameter Covered Electrodes

Typical Shielded Metal Arc Electrode Orientation and Welding Technique for Carbon Steel Electrodes

Type of Joint	Position of Welding	Work Angle, Degrees	Travel Angle, Degrees	Technique of Welding
Groove	Flat	90	5–10*	Backhand
Groove	Horizontal	80–100	5–10	Backhand
Groove	Vertical-Up	90	5–10	Forehand
Groove	Overhead	90	5–10	Backhand
Fillet	Horizontal	45	5–10*	Backhand
Fillet	Vertical-Up	35–55	5–10	Forehand
Fillet	Overhead	30–45	5–10	Backhand

*Travel angle may be 10° to 30° for electrodes with heavy iron powder coatings.

Suggested Amperage Ranges for Austenitic Stainless Steel (Type 3XX) Electrodes

Electrode	Diameter (in.)	Amperage (A)
E3XX-15 and E3XX-16	3/32	40–85
	1/8	55–120
	5/32	85–165
	3/16	100–210
	1/4	205–290

Suggested Amperage Ranges for Copper Alloy Electrodes

Electrode	Diameter (in.)	Amperage (A)
ECuNi	3/32	65–95
	1/8	80–125
	5/32	105–190
	3/16	150–225
ECuAl-A2	3/32	60–80
	1/8	100–120
	5/32	130–150
	3/16	170–190
	1/4	235–255

Suggested Amperage Ranges for Nickel Alloy Steel Electrodes

Electrode	Diameter (in.)	Amperage (A)
ENiCrFe-3	3/32 1/8 5/32 3/16	55–80 80–110 110–140 130–170

Electrode	Diameter (in.)	Amperage (A)
ENiCu-7	3/32 1/8 5/32 3/16	55–80 80–110 110–140 130–170

The electrical resistivity of the core wire in these electrodes is exceptionally high. For this reason, excessive amperage will overheat the electrode and damage the covering, causing arc instability and unacceptable amounts of splatter. Each classification and size of electrode has an optimum amperage range.

Proper Care and Handling of SMAW Electrodes

To ensure satisfactory weld quality, it is important that the SMAW electrodes be handled and stored properly prior to use. The coatings of the electrodes have been carefully designed to provide the necessary operating characteristics and weld properties required for each of the types of electrodes.

The electrode coatings are subject to damage from improper handling and storage practices. The coatings can crack and may fall from the electrode core when experiencing impact loads. This condition can be the result of dropping the electrode packages during transportation of the materials to the job site or by hitting the packages with another object while in storage or during material movement. It is the responsibility of the welder to inspect the electrodes prior to use to ensure that the coating is intact and does not show indications of damage.

The electrode coatings are also hygroscopic, meaning that they are susceptible to absorbing moisture when exposed to the atmosphere. Moisture pick-up in the coating can result in porosity, less than optimum arc characteristics and hydrogen induced cracking. The electrodes can become exposed to moisture conditions if improperly stored or if the packaging becomes damaged during shipping or handling.

It is the responsibility of the welders to protect the electrodes while in their possession. For example, in foggy, misty, and rainy weather, or in conditions of high humidity, the electrodes should be kept in a closed container to prevent direct exposure of the materials to the weather conditions. It is also imperative that the electrodes not be kept or carried in the pockets of a welder, as exposure to perspiration or other body moisture may cause the coating

to introduce excessive amounts of water into the weld.

The recommendations contained in this pocket handbook represent good welding practices. Many welding codes have specific requirements for handling electrodes and for the time of electrode exposure in the atmosphere during the welding operation. The fabricator is responsible for ensuring that the necessary code requirements are fulfilled for each job.

The electrode manufacturer will have recommendations for processing their products. Valuable information can be obtained from the manufacturers for handling, using, and reconditioning SMAW electrodes.

Special Precautions for Low-Hydrogen Electrodes

Hydrogen can have adverse effects on welds in some steels under certain conditions. One source of this hydrogen is moisture in the electrode coverings. For this reason, the proper storage, treatment, and handling of electrodes are necessary.

Electrodes are manufactured to be within acceptable moisture limits, consistent with the type of covering and strength of the weld metal. They are normally packaged in a container which has been designed to provide the degree of moisture protection considered necessary for the type of covering involved.

If there is a possibility that the noncellulosic electrodes may have absorbed excessive moisture, they may be restored by rebaking. Some electrodes require rebaking at a temperature as high as 800°F (425°C) for approximately 1 to 2 hours. The manner in which the electrodes have been produced and the relative humidity and temperature conditions under which the electrodes are stored determines the proper length of time and temperature used for reconditioning. Some typical storage and drying conditions are included in the table on page 21.

Low hydrogen electrodes will adsorb, and possibly absorb, excessive moisture in the coatings when exposed to the atmosphere. Fabrication standards sometimes specify the time limits for exposure to the atmosphere that may be permitted before the electrodes must be redried or otherwise processed prior to use on a job.

Not all coated electrodes are treated the same. For example, cellulosic coverings for E6010 and E6011 electrodes need moisture levels of 3% to 7% for proper operation. Therefore, storage or conditioning above ambient temperature may dry them too much and adversely affect their operation.

Guide to Conditioning and Storage of Steel Electrodes

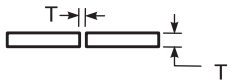
AWS Electrode Classification	Air Conditioned Storage Before Opening RH = Relative Humidity	Holding Temperature After Opening	Reconditioning Temperature and Time to Affect Weld Quality	
			Recondition Step #1	Rebake Step #2
EXX10, EXX11, EXX12, EXX13	Keep Dry @ Room Temperature 40°–120°F 60% (±10%) RH	100°F (±25°)	Not Required NEVER STORE ABOVE 130° OR BELOW 50% RH	Not Required
EXX20, EXX30 Iron Powder EXX14, EXX24, EXX27	90°F (±20°) 50% Max. RH	150°–200°F	250°–300°F ONE HOUR	350°F (±25°) ONE HOUR
			TWO HOUR TOTAL	
Iron Powder–Low Hydrogen EXX18, EXX28 Low Hydrogen EXX15, EXX16	90°F (±20°) 50% Max. RH	300°F (±50°)	500°–600°F ONE HOUR	700°F (±50°) ONE-HALF HOUR
			ONE & ONE-HALF HOUR TOTAL	
Low Hydrogen–High Tensile EXXX15, EXXX16, EXXX18	90°F (±20°) 50% Max. RH	300°F (±50°)	500°–600°F ONE HOUR	650°F (±50°) ONE-HALF HOUR
			ONE & ONE-HALF HOUR TOTAL	

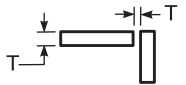
Permissible Atmospheric Exposure of Low-Hydrogen Electrodes

Electrode	Column A (hours)	Column B (hours)
A5.1		
E70XX	4 max	Over 4 to 10 max
E70XXR	9 max	
E70XXHZR	9 max	
E7018M	9 max	
A5.5		
E70XX-X	4 max	Over 4 to 10 max
E80XX-X	2 max	Over 2 to 10 max
E90XX-X	1 max	Over 1 to 5 max
E100XX-X	1/2 max	Over 1/2 to 4 max
E110XX-X	1/2 max	Over 1/2 to 4 max

Notes:
1. Column A: Electrodes exposed to atmosphere for longer periods than shown shall be redried before use.
2. Column B: Electrodes exposed to atmosphere for longer periods than those established by testing shall be redried before use.
3. Entire table: Electrodes shall be issued and held in quivers, or other small open containers. Heated containers are not mandatory.
4. The optional supplemental designator, R, designates a low-hydrogen electrode which has been tested for covering moisture content after exposure to a moist environment for 9 hours and has met the maximum level permitted in ANSI/AWS A5.1-91, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

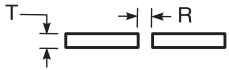
(Taken from AWS D1.1-96)

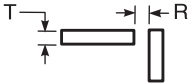




T = 1/16 MAX FOR ALL JOINTS

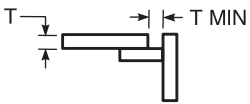
SQUARE GROOVE JOINTS WELDED FROM ONE SIDE





DIM. T	DIM. R
1/8 MAX	0
1/8 TO 1/4	T/2 MAX

SQUARE GROOVE JOINTS WELDED FROM BOTH SIDES

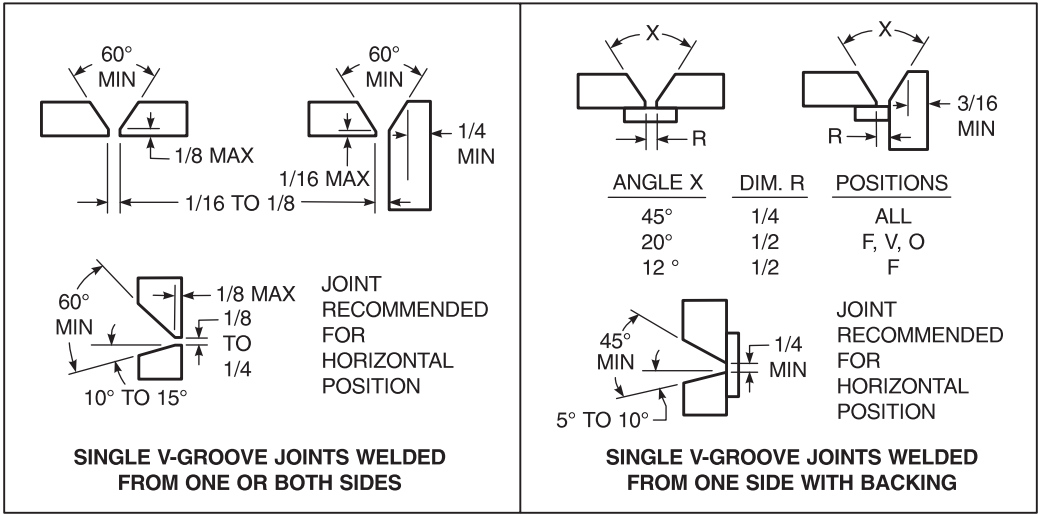


T = 3/16 MAX

SQUARE GROOVE JOINTS WELDED FROM ONE SIDE WITH BACKING

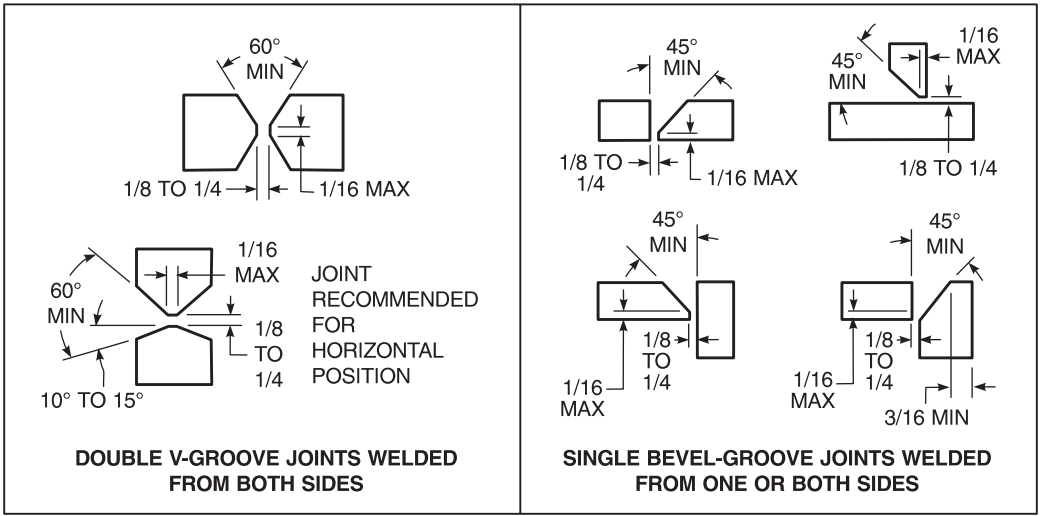
ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications



ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)

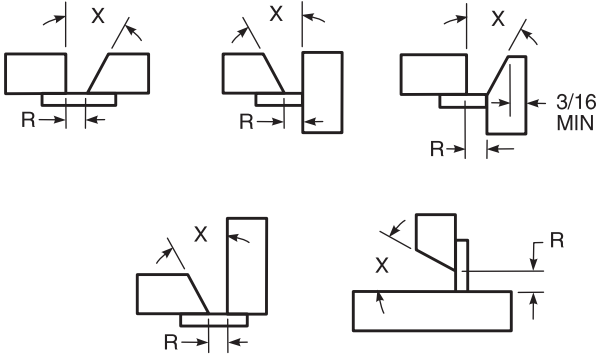


DOUBLE V-GROOVE JOINTS WELDED FROM BOTH SIDES

SINGLE BEVEL-GROOVE JOINTS WELDED FROM ONE OR BOTH SIDES

ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)



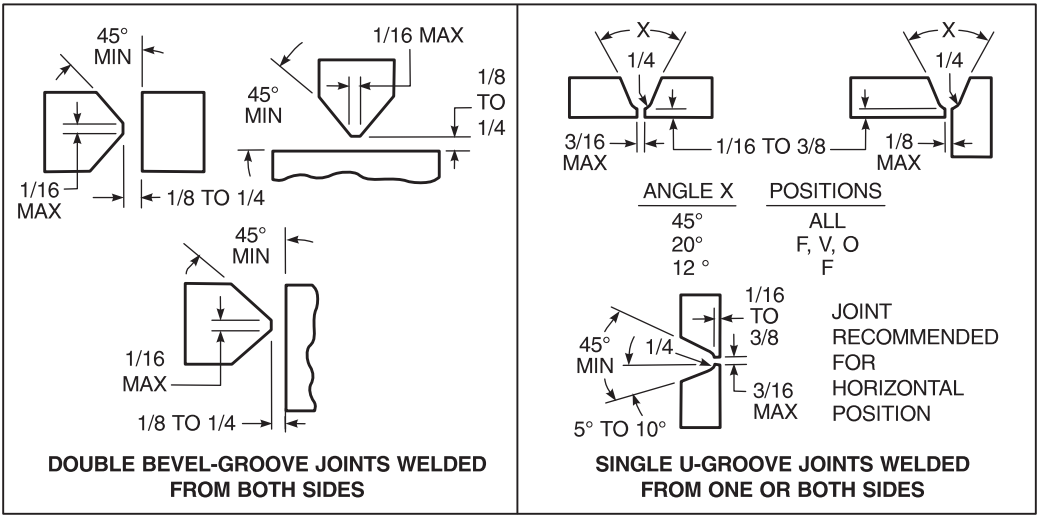
ANGLE X	DIM. R	POSITIONS
45°	1/4	ALL
20°	3/8	ALL
12 °	3/8	F, V, O

ANGLE X	DIM. R	POSITIONS
45°	1/4	ALL
35°	3/8	ALL

SINGLE BEVEL-GROOVE JOINTS WELDED FROM ONE SIDE WITH BACKING

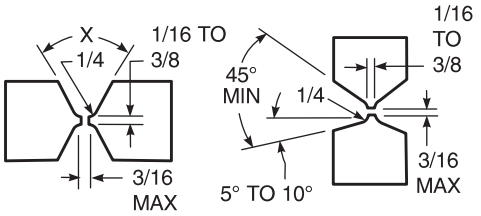
ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)



ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

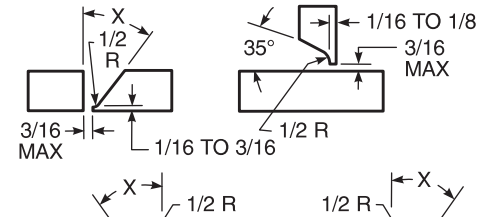
Suggested Joint Designs for SMAW Applications (Continued)



JOINT RECOMMENDED FOR HORIZONTAL POSITION

ANGLE X	POSITIONS
45°	ALL
20°	F, V, O

DOUBLE U-GROOVE JOINTS WELDED FROM BOTH SIDES

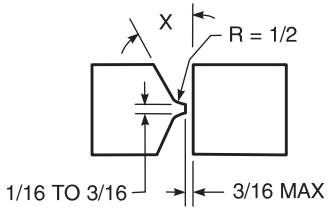


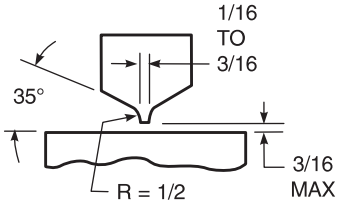
ANGLE X	POSITIONS
35°	ALL
25°	F, V, O

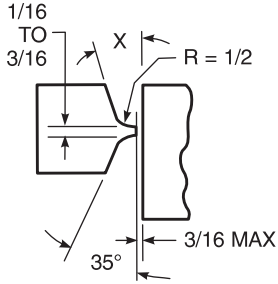
SINGLE J-GROOVE JOINTS WELDED FROM ONE OR BOTH SIDES

ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)





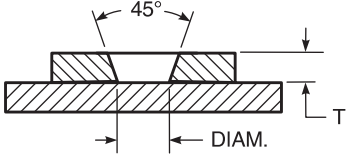


ANGLE X	POSITIONS
35° MIN	ALL
25° MIN	F, V, O

DOUBLE J-GROOVE JOINTS WELDED FROM BOTH SIDES

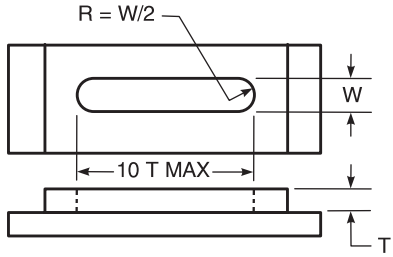
ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)



DIM. T	DIAM.
UNDER 1/8	1/4 MIN
1/8 TO 1/2	2 T MIN
OVER 1/2	T + 1/2

JOINT FOR PLUG WELD



DIM. T	DIM. W
UNDER 1/8	2 T MIN
1/8 AND OVER	1-1/2 T MIN

JOINT FOR SLOT WELD

ALL DIMENSIONS IN INCHES EXCEPT ANGLES.

Suggested Joint Designs for SMAW Applications (Continued)

Basic Welding Symbols and Their Location Significance

Refer to AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*, for more information.

Location Significance	Fillet	Plug or Slot	Spot or Projection	Stud	Seam	Back or Backing	Surfacing	Flange Corner	Flange Edge
Arrow Side									
Other Side				Not Used			Not Used		
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used
No Arrow Side or Other Side Significance	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used	Not Used

Basic Welding Symbols and Their Location Significance (Continued)

Location Significance	Groove							Scarf for Brazed Joint
	Square	V	Bevel	U	J	Flare-V	Flare-Bevel	
Arrow Side								
Other Side								
Both Sides								
No Arrow Side or Other Side Significance		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used

Location of Elements of a Welding Symbol