

# Guidelines For Shielded Metal Arc Welding (SMAW)

# TABLE OF CONTENTS

---

<b>SECTION 1 – SAFETY PRECAUTIONS - READ BEFORE USING</b> .....	<b>1</b>
1-1. Symbol Usage .....	1
1-2. Arc Welding Hazards .....	1
1-3. Additional Symbols For Installation, Operation, And Maintenance .....	3
1-4. California Proposition 65 Warnings .....	4
1-5. Principal Safety Standards .....	4
1-6. EMF Information .....	4
<b>SECTION 2 – PRINCIPLES OF SHIELDED METAL ARC WELDING (SMAW)</b> .....	<b>5</b>
<b>SECTION 3 – SHIELDED METAL ARC WELDING (SMAW) PROCEDURE</b> .....	<b>6</b>
3-1. Typical Stick Welding Set-Up .....	6
3-2. Electrode And Amperage Selection Chart .....	7
3-3. Striking An Arc – Scratch Start Technique .....	8
3-4. Striking An Arc – Tapping Technique .....	8
3-5. Positioning Electrode Holder .....	9
3-6. Electrode Movement During Welding .....	10
3-7. Conditions That Affect Weld Bead Shape .....	11
3-8. Poor Weld Bead Characteristics .....	12
3-9. Good Weld Bead Characteristics .....	12
3-10. Typical Weld Joints .....	13
3-11. Welding Groove (Butt) Joints .....	14
3-12. Welding Tee Joints .....	15
3-13. Welding Lap Joints .....	15
3-14. Welding Horizontal Beads And Groove (Butt) Joints .....	16
3-15. Welding Vertical Beads And Groove (Butt) Joints .....	17
3-16. Welding Vertical Tee Joints And Lap Joints .....	18
3-17. Welding Overhead Groove (Butt) Joints And Tee Joints .....	19
3-18. Weld Test .....	20
<b>SECTION 4 – WELDING TROUBLESHOOTING</b> .....	<b>20</b>
4-1. Porosity .....	20
4-2. Excessive Spatter .....	21
4-3. Incomplete Fusion .....	21
4-4. Lack Of Penetration .....	21
4-5. Excessive Penetration .....	22
4-6. Burn-Through .....	22
4-7. Waviness Of Bead .....	22
4-8. Distortion .....	22

# SECTION 1 – SAFETY PRECAUTIONS - READ BEFORE USING

som 2018-01

**⚠** Protect yourself and others from injury — read, follow, and save these important safety precautions and operating instructions.

## 1-1. Symbol Usage



**DANGER!** – Indicates a hazardous situation which, if not avoided, will result in death or serious injury. The possible hazards are shown in the adjoining symbols or explained in the text.



Indicates a hazardous situation which, if not avoided, could result in death or serious injury. The possible hazards are shown in the adjoining symbols or explained in the text.

**NOTICE** – Indicates statements not related to personal injury.

 Indicates special instructions.



This group of symbols means Warning! Watch Out! ELECTRIC SHOCK, MOVING PARTS, and HOT PARTS hazards. Consult symbols and related instructions below for necessary actions to avoid the hazards.

## 1-2. Arc Welding Hazards



The symbols shown below are used throughout this manual to call attention to and identify possible hazards. When you see the symbol, watch out, and follow the related instructions to avoid the hazard. The safety information given below is only a summary of the more complete safety information found in the Safety Standards listed in Section 1-5. Read and follow all Safety Standards.



Only qualified persons should install, operate, maintain, and repair this equipment. A qualified person is defined as one who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training and experience, has successfully demonstrated ability to solve or resolve problems relating to the subject matter, the work, or the project and has received safety training to recognize and avoid the hazards involved.



During operation, keep everybody, especially children, away.



### ELECTRIC SHOCK can kill.

Touching live electrical parts can cause fatal shocks or severe burns. The electrode and work circuit is electrically live whenever the output is on. The input power circuit and machine internal circuits are also live when power is on. In semiautomatic or automatic wire welding, the wire, wire reel, drive roll housing, and all metal parts touching the welding wire are electrically live. Incorrectly installed or improperly grounded equipment is a hazard.

- Do not touch live electrical parts.

- Wear dry, hole-free insulating gloves and body protection.
- Insulate yourself from work and ground using dry insulating mats or covers big enough to prevent any physical contact with the work or ground.
- Do not use AC weld output in damp, wet, or confined spaces, or if there is a danger of falling.
- Use AC output ONLY if required for the welding process.
- If AC output is required, use remote output control if present on unit.
- Additional safety precautions are required when any of the following electrically hazardous conditions are present: in damp locations or while wearing wet clothing; on metal structures such as floors, gratings, or scaffolds; when in cramped positions such as sitting, kneeling, or lying; or when there is a high risk of unavoidable or accidental contact with the workpiece or ground. For these conditions, use the following equipment in order presented: 1) a semiautomatic DC constant voltage (wire) welder, 2) a DC manual (stick) welder, or 3) an AC welder with reduced open-circuit voltage. In most situations, use of a DC, constant voltage wire welder is recommended. And, do not work alone!
- Disconnect input power or stop engine before installing or servicing this equipment. Lockout/tagout input power according to OSHA 29 CFR 1910.147 (see Safety Standards).

- Properly install, ground, and operate this equipment according to its Owner's Manual and national, state, and local codes.
- Always verify the supply ground – check and be sure that input power cord ground wire is properly connected to ground terminal in disconnect box or that cord plug is connected to a properly grounded receptacle outlet.
- When making input connections, attach proper grounding conductor first – double-check connections.
- Keep cords dry, free of oil and grease, and protected from hot metal and sparks.
- Frequently inspect input power cord and ground conductor for damage or bare wiring – replace immediately if damaged – bare wiring can kill.
- Turn off all equipment when not in use.
- Do not use worn, damaged, undersized, or repaired cables.
- Do not drape cables over your body.
- If earth grounding of the workpiece is required, ground it directly with a separate cable.
- Do not touch electrode if you are in contact with the work, ground, or another electrode from a different machine.
- Do not touch electrode holders connected to two welding machines at the same time since double open-circuit voltage will be present.
- Use only well-maintained equipment. Repair or replace damaged parts at once. Maintain unit according to manual.
- Wear a safety harness if working above floor level.
- Keep all panels and covers securely in place.
- Clamp work cable with good metal-to-metal contact to workpiece or worktable as near the weld as practical.
- Insulate work clamp when not connected to workpiece to prevent contact with any metal object.
- Do not connect more than one electrode or work cable to any single weld output terminal. Disconnect cable for process not in use.
- Use GFCI protection when operating auxiliary equipment in damp or wet locations.

### SIGNIFICANT DC VOLTAGE exists in inverter welding power sources AFTER removal of input power.

- Turn off unit, disconnect input power, and discharge input capacitors according to instructions in Manual before touching any parts.



### HOT PARTS can burn.

- Do not touch hot parts bare handed.
- Allow cooling period before working on equipment.
- To handle hot parts, use proper tools and/or wear heavy, insulated welding gloves and clothing to prevent burns.



### FUMES AND GASES can be hazardous.

Welding produces fumes and gases. Breathing these fumes and gases can be hazardous to your health.

- Keep your head out of the fumes. Do not breathe the fumes.
- Ventilate the work area and/or use local forced ventilation at the arc to remove welding fumes and gases. The recommended way to determine adequate ventilation is to sample for the composition and quantity of fumes and gases to which personnel are exposed.
- If ventilation is poor, wear an approved air-supplied respirator.
- Read and understand the Safety Data Sheets (SDSs) and the manufacturer's instructions for adhesives, coatings, cleaners, consumables, coolants, degreasers, fluxes, and metals.
- Work in a confined space only if it is well ventilated, or while wearing an air-supplied respirator. Always have a trained watchperson nearby. Welding fumes and gases can displace air and lower the oxygen level causing injury or death. Be sure the breathing air is safe.
- Do not weld in locations near degreasing, cleaning, or spraying operations. The heat and rays of the arc can react with vapors to form highly toxic and irritating gases.
- Do not weld on coated metals, such as galvanized, lead, or cadmium plated steel, unless the coating is removed from the weld area, the area is well ventilated, and while wearing an air-supplied respirator. The coatings and any metals containing these elements can give off toxic fumes if welded.



### ARC RAYS can burn eyes and skin.

Arc rays from the welding process produce intense visible and invisible (ultraviolet and infrared) rays that can burn eyes and skin. Sparks fly off from the weld.

- Wear an approved welding helmet fitted with a proper shade of filter lenses to protect your face and eyes from arc rays and sparks when welding or watching (see ANSI Z49.1 and Z87.1 listed in Safety Standards).
- Wear approved safety glasses with side shields under your helmet.
- Use protective screens or barriers to protect others from flash, glare and sparks; warn others not to watch the arc.
- Wear body protection made from durable, flame-resistant material (leather, heavy cotton, wool). Body protection includes oil-free clothing such as leather gloves, heavy shirt, cuffless trousers, high shoes, and a cap.

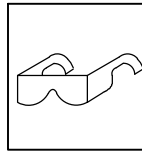


### WELDING can cause fire or explosion.

Welding on closed containers, such as tanks, drums, or pipes, can cause them to blow up. Sparks can fly off from the welding arc. The flying sparks, hot workpiece, and hot equipment can cause fires and burns. Accidental contact of electrode to metal objects can cause sparks, explosion, overheating, or fire. Check and be sure the area is safe before doing any welding.

- Remove all flammables within 35 ft (10.7 m) of the welding arc. If this is not possible, tightly cover them with approved covers.
- Do not weld where flying sparks can strike flammable material.
- Protect yourself and others from flying sparks and hot metal.
- Be alert that welding sparks and hot materials from welding can easily go through small cracks and openings to adjacent areas.
- Watch for fire, and keep a fire extinguisher nearby.
- Be aware that welding on a ceiling, floor, bulkhead, or partition can cause fire on the hidden side.

- Do not cut or weld on tire rims or wheels. Tires can explode if heated. Repaired rims and wheels can fail. See OSHA 29 CFR 1910.177 listed in Safety Standards.
- Do not weld on containers that have held combustibles, or on closed containers such as tanks, drums, or pipes unless they are properly prepared according to AWS F4.1 and AWS A6.0 (see Safety Standards).
- Do not weld where the atmosphere can contain flammable dust, gas, or liquid vapors (such as gasoline).
- Connect work cable to the work as close to the welding area as practical to prevent welding current from traveling long, possibly unknown paths and causing electric shock, sparks, and fire hazards.
- Do not use welder to thaw frozen pipes.
- Remove stick electrode from holder or cut off welding wire at contact tip when not in use.
- Wear body protection made from durable, flame-resistant material (leather, heavy cotton, wool). Body protection includes oil-free clothing such as leather gloves, heavy shirt, cuffless trousers, high shoes, and a cap.
- Remove any combustibles, such as a butane lighter or matches, from your person before doing any welding.
- After completion of work, inspect area to ensure it is free of sparks, glowing embers, and flames.
- Use only correct fuses or circuit breakers. Do not oversize or bypass them.
- Follow requirements in OSHA 1910.252 (a) (2) (iv) and NFPA 51B for hot work and have a fire watcher and extinguisher nearby.
- Read and understand the Safety Data Sheets (SDSs) and the manufacturer's instructions for adhesives, coatings, cleaners, consumables, coolants, degreasers, fluxes, and metals.



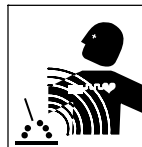
### FLYING METAL or DIRT can injure eyes.

- Welding, chipping, wire brushing, and grinding cause sparks and flying metal. As welds cool, they can throw off slag.
- Wear approved safety glasses with side shields even under your welding helmet.



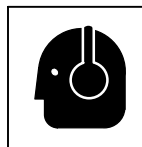
### BUILDUP OF GAS can injure or kill.

- Shut off compressed gas supply when not in use.
- Always ventilate confined spaces or use approved air-supplied respirator.



### ELECTRIC AND MAGNETIC FIELDS (EMF) can affect Implanted Medical Devices.

- Wearers of Pacemakers and other Implanted Medical Devices should keep away.
- Implanted Medical Device wearers should consult their doctor and the device manufacturer before going near arc welding, spot welding, gouging, plasma arc cutting, or induction heating operations.



### NOISE can damage hearing.

Noise from some processes or equipment can damage hearing.

- Wear approved ear protection if noise level is high.



### **CYLINDERS can explode if damaged.**

Compressed gas cylinders contain gas under high pressure. If damaged, a cylinder can explode. Since gas cylinders are normally part of the welding process, be sure to treat them carefully.

- Protect compressed gas cylinders from excessive heat, mechanical shocks, physical damage, slag, open flames, sparks, and arcs.
- Install cylinders in an upright position by securing to a stationary support or cylinder rack to prevent falling or tipping.
- Keep cylinders away from any welding or other electrical circuits.
- Never drape a welding torch over a gas cylinder.
- Never allow a welding electrode to touch any cylinder.

- Never weld on a pressurized cylinder – explosion will result.
- Use only correct compressed gas cylinders, regulators, hoses, and fittings designed for the specific application; maintain them and associated parts in good condition.
- Turn face away from valve outlet when opening cylinder valve. Do not stand in front of or behind the regulator when opening the valve.
- Keep protective cap in place over valve except when cylinder is in use or connected for use.
- Use the proper equipment, correct procedures, and sufficient number of persons to lift, move, and transport cylinders.
- Read and follow instructions on compressed gas cylinders, associated equipment, and Compressed Gas Association (CGA) publication P-1 listed in Safety Standards.

## **1-3. Additional Symbols For Installation, Operation, And Maintenance**



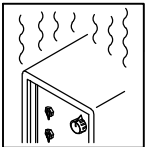
### **FIRE OR EXPLOSION hazard.**

- Do not install or place unit on, over, or near combustible surfaces.
- Do not install unit near flammables.
- Do not overload building wiring – be sure power supply system is properly sized, rated, and protected to handle this unit.



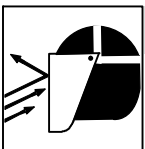
### **FALLING EQUIPMENT can injure.**

- Use lifting eye to lift unit only, NOT running gear, gas cylinders, or any other accessories.
- Use correct procedures and equipment of adequate capacity to lift and support unit.
- If using lift forks to move unit, be sure forks are long enough to extend beyond opposite side of unit.
- Keep equipment (cables and cords) away from moving vehicles when working from an aerial location.
- Follow the guidelines in the Applications Manual for the Revised NIOSH Lifting Equation (Publication No. 94-110) when manually lifting heavy parts or equipment.



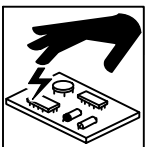
### **OVERUSE can cause OVERHEATING**

- Allow cooling period; follow rated duty cycle.
- Reduce current or reduce duty cycle before starting to weld again.
- Do not block or filter airflow to unit.



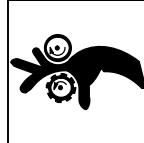
### **FLYING SPARKS can injure.**

- Wear a face shield to protect eyes and face.
- Shape tungsten electrode only on grinder with proper guards in a safe location wearing proper face, hand, and body protection.
- Sparks can cause fires — keep flammables away.



### **STATIC (ESD) can damage PC boards.**

- Put on grounded wrist strap BEFORE handling boards or parts.
- Use proper static-proof bags and boxes to store, move, or ship PC boards.



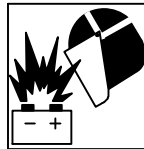
### **MOVING PARTS can injure.**

- Keep away from moving parts.
- Keep away from pinch points such as drive rolls.



### **WELDING WIRE can injure.**

- Do not press gun trigger until instructed to do so.
- Do not point gun toward any part of the body, other people, or any metal when threading welding wire.



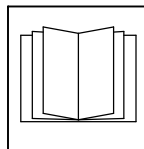
### **BATTERY EXPLOSION can injure.**

- Do not use welder to charge batteries or jump start vehicles unless it has a battery charging feature designed for this purpose.



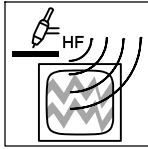
### **MOVING PARTS can injure.**

- Keep away from moving parts such as fans.
- Keep all doors, panels, covers, and guards closed and securely in place.
- Have only qualified persons remove doors, panels, covers, or guards for maintenance and troubleshooting as necessary.
- Reinstall doors, panels, covers, or guards when maintenance is finished and before reconnecting input power.



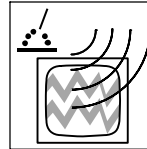
### **READ INSTRUCTIONS.**

- Read and follow all labels and the Owner's Manual carefully before installing, operating, or servicing unit. Read the safety information at the beginning of the manual and in each section.
- Use only genuine replacement parts from the manufacturer.
- Perform installation, maintenance, and service according to the Owner's Manuals, industry standards, and national, state, and local codes.



#### H.F. RADIATION can cause interference.

- High-frequency (H.F.) can interfere with radio navigation, safety services, computers, and communications equipment.
- Have only qualified persons familiar with electronic equipment perform this installation.
- The user is responsible for having a qualified electrician promptly correct any interference problem resulting from the installation.
- If notified by the FCC about interference, stop using the equipment at once.
- Have the installation regularly checked and maintained.
- Keep high-frequency source doors and panels tightly shut, keep spark gaps at correct setting, and use grounding and shielding to minimize the possibility of interference.



#### ARC WELDING can cause interference.

- Electromagnetic energy can interfere with sensitive electronic equipment such as computers and computer-driven equipment such as robots.
- Be sure all equipment in the welding area is electromagnetically compatible.
- To reduce possible interference, keep weld cables as short as possible, close together, and down low, such as on the floor.
- Locate welding operation 100 meters from any sensitive electronic equipment.
- Be sure this welding machine is installed and grounded according to this manual.
- If interference still occurs, the user must take extra measures such as moving the welding machine, using shielded cables, using line filters, or shielding the work area.

### 1-4. California Proposition 65 Warnings

**⚠ WARNING:** This product can expose you to chemicals including lead, which are known to the state of California to cause cancer and birth defects or other reproductive harm.

For more information, go to [www.P65Warnings.ca.gov](http://www.P65Warnings.ca.gov)

### 1-5. Principal Safety Standards

*Safety in Welding, Cutting, and Allied Processes*, ANSI Standard Z49.1, is available as a free download from the American Welding Society at <http://www.aws.org> or purchased from Global Engineering Documents (phone: 1-877-413-5184, website: [www.global.ihs.com](http://www.global.ihs.com)).

*Safe Practices for the Preparation of Containers and Piping for Welding and Cutting*, American Welding Society Standard AWS F4.1, from Global Engineering Documents (phone: 1-877-413-5184, website: [www.global.ihs.com](http://www.global.ihs.com)).

*Safe Practices for Welding and Cutting Containers that have Held Combustibles*, American Welding Society Standard AWS A6.0, from Global Engineering Documents (phone: 1-877-413-5184, website: [www.global.ihs.com](http://www.global.ihs.com)).

*National Electrical Code*, NFPA Standard 70, from National Fire Protection Association, Quincy, MA 02169 (phone: 1-800-344-3555, website: [www.nfpa.org](http://www.nfpa.org) and [www.sparky.org](http://www.sparky.org)).

*Safe Handling of Compressed Gases in Cylinders*, CGA Pamphlet P-1, from Compressed Gas Association, 14501 George Carter Way, Suite 103, Chantilly, VA 20151 (phone: 703-788-2700, website: [www.cganet.com](http://www.cganet.com)).

*Safety in Welding, Cutting, and Allied Processes*, CSA Standard W117.2, from Canadian Standards Association, Standards Sales, 5060 Spectrum Way, Suite 100, Mississauga, Ontario, Canada L4W 5N5 (phone: 800-463-6727, website: [www.csagroup.org](http://www.csagroup.org)).

*Safe Practice For Occupational And Educational Eye And Face Protection*, ANSI Standard Z87.1, from American National Standards Institute, 25 West 43rd Street, New York, NY 10036 (phone: 212-642-4900, website: [www.ansi.org](http://www.ansi.org)).

*Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, NFPA Standard 51B, from National Fire Protection Association, Quincy, MA 02169 (phone: 1-800-344-3555, website: [www.nfpa.org](http://www.nfpa.org)).

OSHA, Occupational Safety and Health Standards for General Industry, Title 29, Code of Federal Regulations (CFR), Part 1910.177 Subpart N, Part 1910 Subpart Q, and Part 1926, Subpart J, from U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954 (phone: 1-866-512-1800) (there are 10 OSHA Regional Offices—phone for Region 5, Chicago, is 312-353-2220, website: [www.osha.gov](http://www.osha.gov)).

*Applications Manual for the Revised NIOSH Lifting Equation*, The National Institute for Occupational Safety and Health (NIOSH), 1600 Clifton Rd, Atlanta, GA 30329-4027 (phone: 1-800-232-4636, website: [www.cdc.gov/NIOSH](http://www.cdc.gov/NIOSH)).

### 1-6. EMF Information

Electric current flowing through any conductor causes localized electric and magnetic fields (EMF). The current from arc welding (and allied processes including spot welding, gouging, plasma arc cutting, and induction heating operations) creates an EMF field around the welding circuit. EMF fields can interfere with some medical implants, e.g. pacemakers. Protective measures for persons wearing medical implants have to be taken. For example, restrict access for passers-by or conduct individual risk assessment for welders. All welders should use the following procedures in order to minimize exposure to EMF fields from the welding circuit:

1. Keep cables close together by twisting or taping them, or using a cable cover.
2. Do not place your body between welding cables. Arrange cables to one side and away from the operator.
3. Do not coil or drape cables around your body.

4. Keep head and trunk as far away from the equipment in the welding circuit as possible.
5. Connect work clamp to workpiece as close to the weld as possible.
6. Do not work next to, sit or lean on the welding power source.
7. Do not weld whilst carrying the welding power source or wire feeder.

#### About Implanted Medical Devices:

Implanted Medical Device wearers should consult their doctor and the device manufacturer before performing or going near arc welding, spot welding, gouging, plasma arc cutting, or induction heating operations. If cleared by your doctor, then following the above procedures is recommended.

## SECTION 2 – PRINCIPLES OF SHIELDED METAL ARC WELDING (SMAW)

Shielded Metal Arc Welding (SMAW) or Stick welding is a process which melts and joins metals by heating them with an arc between a coated metal electrode and the workpiece. The electrode outer coating, called flux, assists in creating the arc and provides the shielding gas and slag covering to protect the weld from contamination. The electrode core provides most of the weld filler metal.

When the electrode is moved along the workpiece at the correct speed the metal deposits in a uniform layer called a bead.

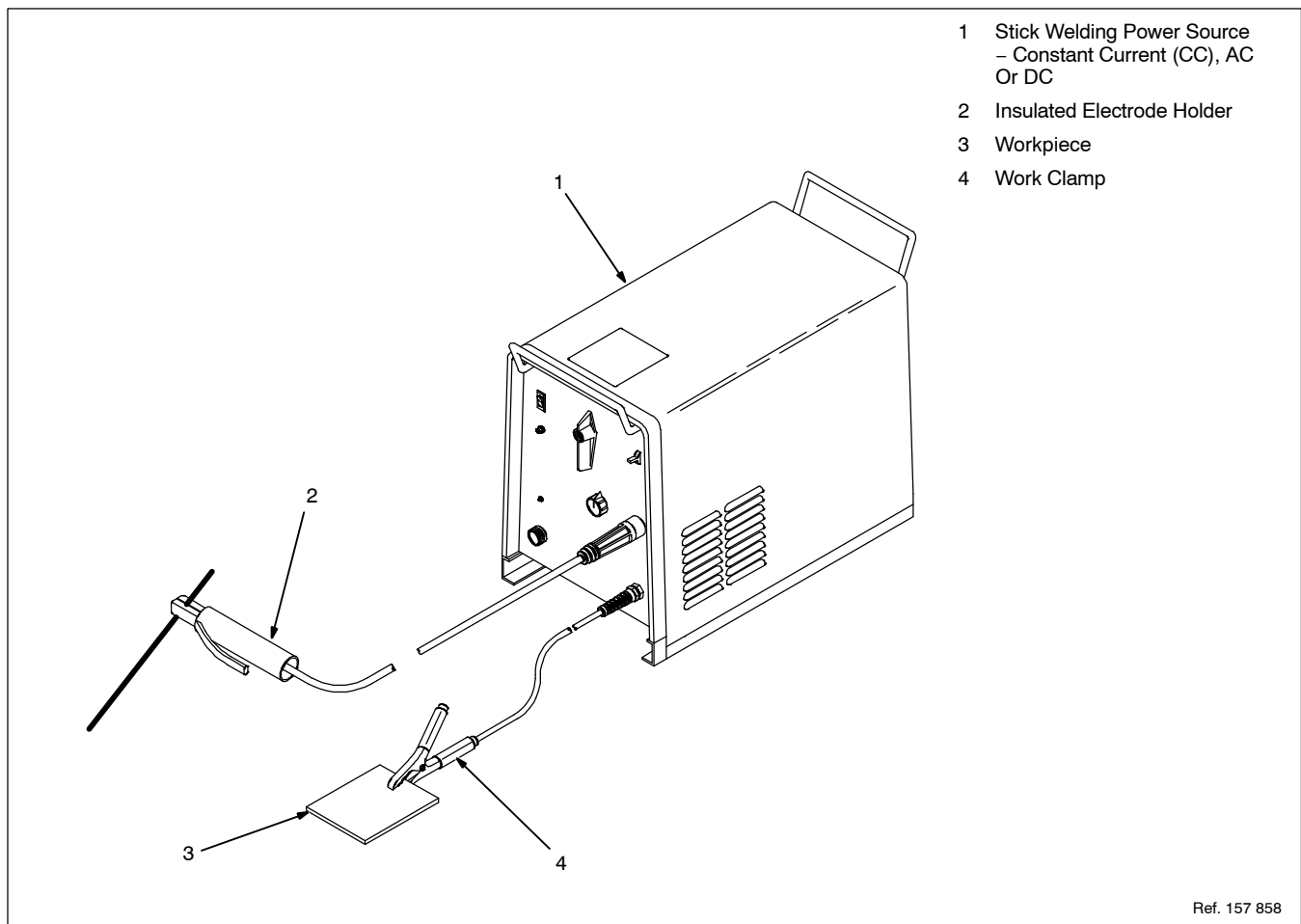
The Stick welding power source provides constant current (CC) and may be either alternating current (AC) or direct current (DC), depending on the electrode being used. The best welding characteristics are usually obtained using DC power sources.

The power in a welding circuit is measured in voltage and current. The voltage (Volts) is governed by the arc length between the electrode and the workpiece and is influenced by electrode diameter. Current is a more practical measure of the power in a weld circuit and is measured in amperes (Amps).

The amperage needed to weld depends on electrode diameter, the size and thickness of the pieces to be welded, and the position of the welding. Thin metals require less current than thick metals, and a small electrode requires less amperage than a large one.

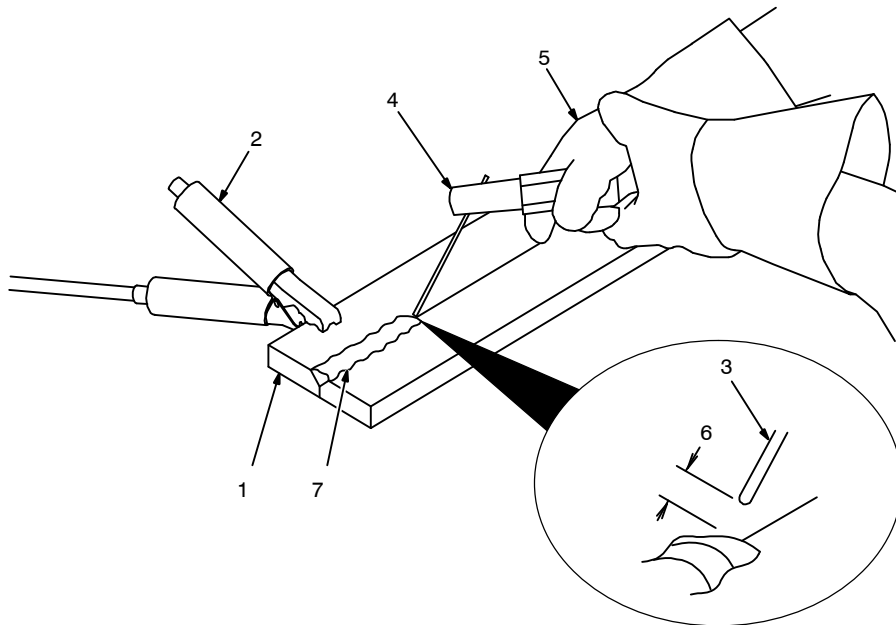
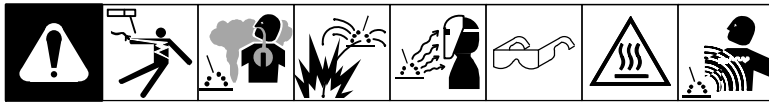
It is preferable to weld on work in the flat or horizontal position. However, when forced to weld in vertical or overhead positions it is helpful to reduce the amperage from that used when welding horizontally. Best welding results are achieved by maintaining a short arc, moving the electrode at a uniform speed, and feeding the electrode downward at a constant speed as it melts.

More specific information on the Stick welding procedure is provided in the following sections.

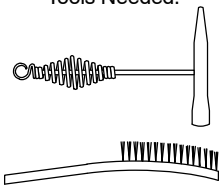


# SECTION 3 – SHIELDED METAL ARC WELDING (SMAW) PROCEDURE

## 3-1. Typical Stick Welding Set-Up



Tools Needed:



**⚠** Welding current starts as soon as electrode touches the workpiece.

**⚠** Weld current can damage electronic parts in vehicles. Disconnect both battery cables before welding on a vehicle. Place work clamp as close to the weld as possible.

**🧥** Always wear appropriate personal protective clothing.

1 Workpiece

Make sure workpiece is clean before welding.

2 Work Clamp

Place as close to the weld as possible.

3 Electrode

Before striking an arc, insert an electrode in the electrode holder. A small diameter electrode requires less current than a large one. Follow recommendations of the electrode manufacturer when setting weld amperage (see Section 3-2).

4 Insulated Electrode Holder

5 Electrode Holder Position

6 Arc Length

Arc length is the distance from the electrode to the workpiece. A short arc with correct amperage will give a sharp, crackling sound. Correct arc length is related to electrode diameter. Examine the weld bead to determine if the arc length is correct.

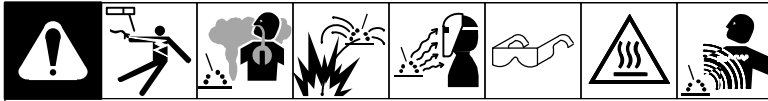
Arc length for 1/16 and 3/32 in. diameter electrodes should be about 1/16 in. (1.6 mm); arc length for 1/8 and 5/32 in. electrodes should be about 1/8 in. (3 mm).

7 Slag

Use a chipping hammer and wire brush to remove slag. Remove slag and check weld bead before making another weld pass.



### 3-2. Electrode And Amperage Selection Chart

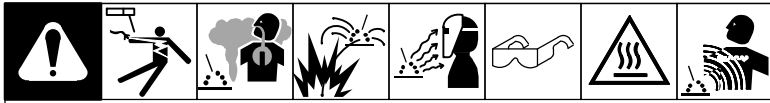


ELECTRODE	DIAMETER	AMPERAGE RANGE									
		50	100	150	200	250	300	350	400	450	
6010 & 6011	3/32	█									
	1/8		█								
	5/32			█							
	3/16				█						
	7/32					█					
6013	1/4					█					
	1/16	█									
	5/64		█								
	3/32			█							
	1/8				█						
	5/32					█					
	3/16						█				
7014	7/32						█				
	1/4							█			
	3/32								█		
	1/8									█	
	5/32										█
7018	3/16										█
	7/32										
	1/4										
	5/32										
	3/16										
7024	7/32										
	3/16										
	5/32										
	1/8										
	3/32										
Ni-CI	1/4										
	3/32										
	1/8										
	5/32										
308L	3/16										
	1/8										
	5/32										

ELECTRODE	DC*	AC	POSITION	PENETRATION	USAGE
6010	EP		ALL	DEEP	MIN. PREP ROUGH HIGH SPATTER
6011	EP	✓	ALL	DEEP	
6013	EP,EN	✓	ALL	LOW	GENERAL
7014	EP,EN	✓	ALL	MED	SMOOTH, EASY, FAST
7018	EP	✓	ALL	MED	LOW HYDROGEN, STRONG
7024	EP,EN	✓	FLAT HORIZ FILLET	LOW	SMOOTH, EASY, FASTER
NI-CL	EP	✓	ALL	LOW	CAST IRON
308L	EP	✓	ALL	LOW	STAINLESS

\*EP = ELECTRODE POSITIVE (REVERSE POLARITY)  
EN = ELECTRODE NEGATIVE (STRAIGHT POLARITY)

### 3-3. Striking An Arc – Scratch Start Technique

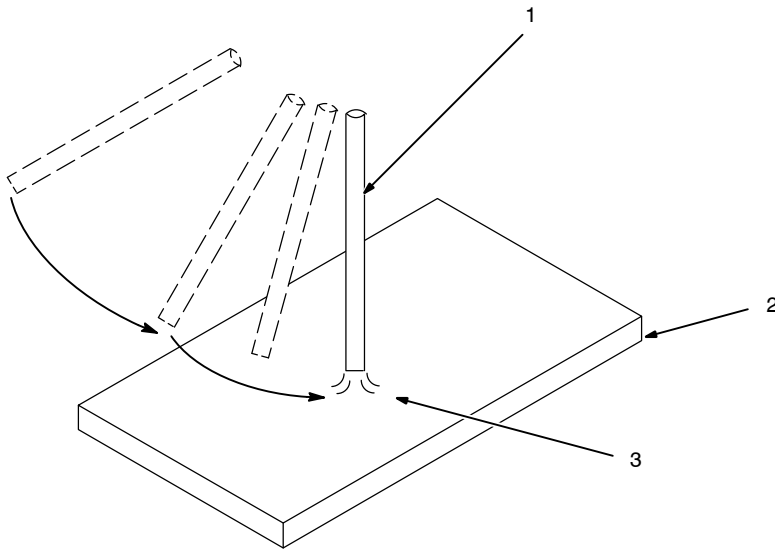


**⚠** Welding current starts as soon as electrode touches the workpiece.

*The scratch-start technique is preferred for ac welding.*

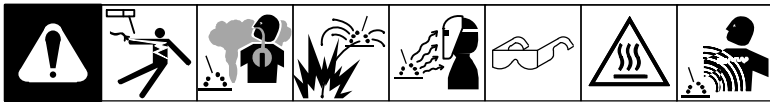
- 1 Electrode
- 2 Workpiece
- 3 Arc

Drag electrode across workpiece like striking a match; immediately lift electrode slightly after touching work. If arc goes out, electrode was lifted too high. If electrode sticks to workpiece, use a quick twist to free it.



S-0049

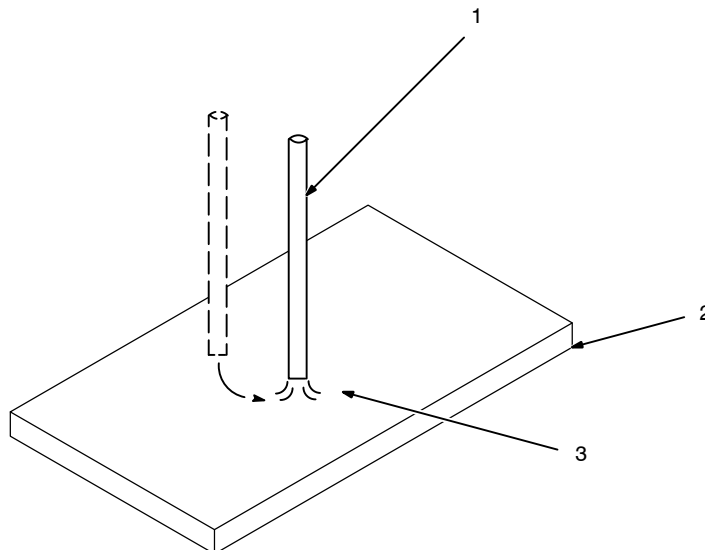
### 3-4. Striking An Arc – Tapping Technique



**⚠** Welding current starts as soon as electrode touches the workpiece.

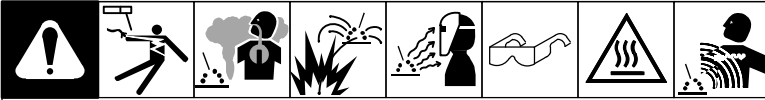
- 1 Electrode
- 2 Workpiece
- 3 Arc

Bring electrode straight down to workpiece; then lift slightly to start arc. If arc goes out, electrode was lifted too high. If electrode sticks to workpiece, use a quick twist to free it.



S-0049

### 3-5. Positioning Electrode Holder

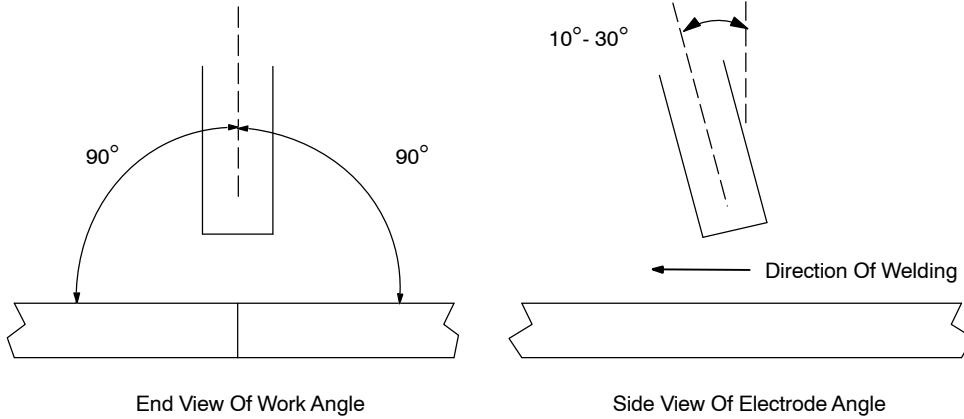


After learning to start and hold an arc, practice running beads of weld metal on flat plates using a full electrode.

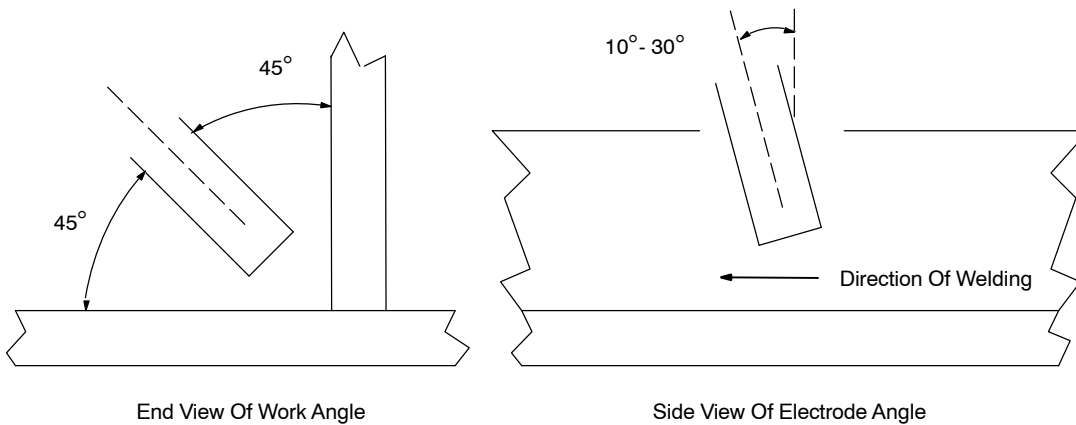
Hold the electrode nearly perpendicular to the work, although tilting it ahead (in the direction of travel) will be helpful.

*To produce the best results, hold a short arc, travel at a uniform speed, and feed the electrode downward at a constant rate as it melts.*

#### Groove Welds



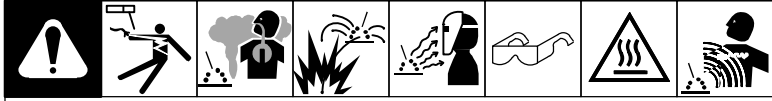
#### Fillet Welds



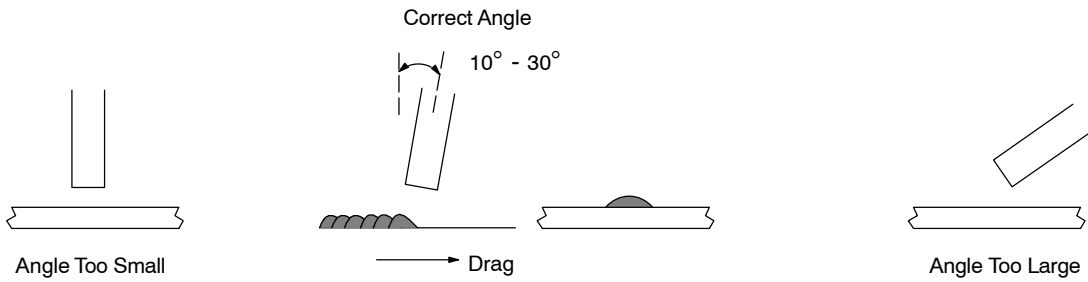


### 3-7. Conditions That Affect Weld Bead Shape

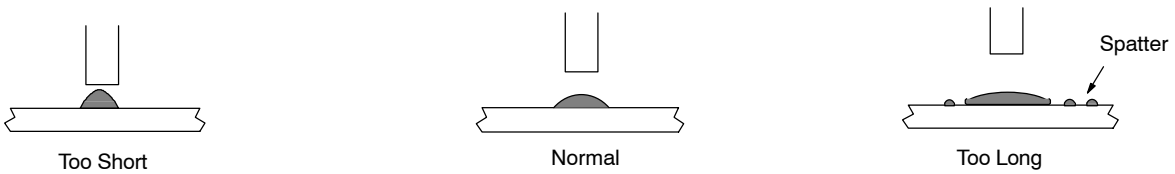
☞ Weld bead shape is affected by electrode angle, arc length, travel speed, and thickness of base metal.



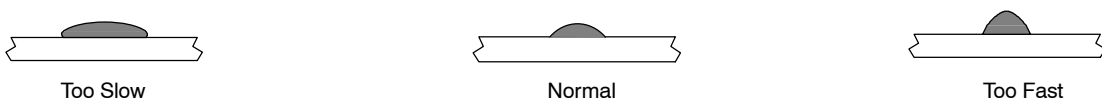
#### Electrode Angle



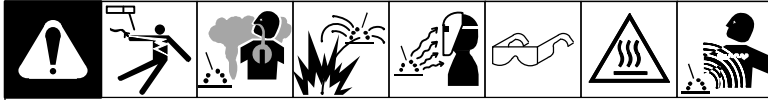
#### Arc Length



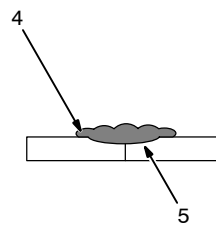
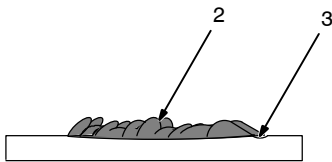
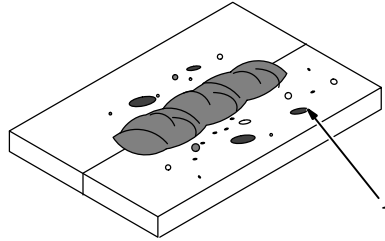
#### Travel Speed



### 3-8. Poor Weld Bead Characteristics

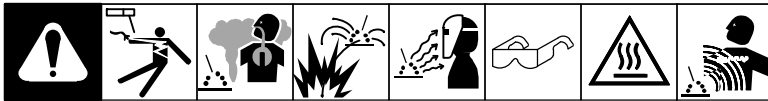


- 1 Large Spatter Deposits
- 2 Rough, Uneven Bead
- 3 Slight Crater During Welding
- 4 Bad Overlap
- 5 Poor Penetration

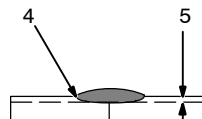
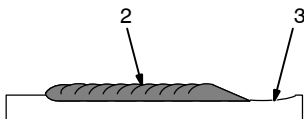
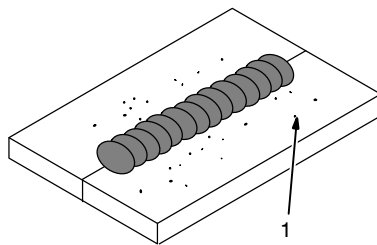


S-0053-A

### 3-9. Good Weld Bead Characteristics

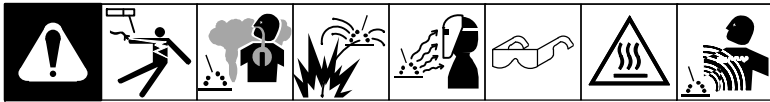


- 1 Fine Spatter
- 2 Uniform Bead
- 3 Moderate Crater During Welding
- 4 No Overlap
- 5 Good Penetration Into Base Metal

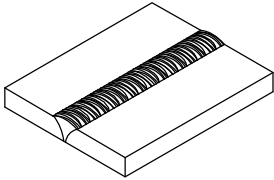


S-0052-B

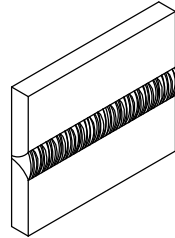
### 3-10. Typical Weld Joints



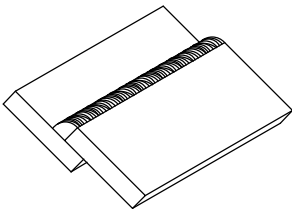
Groove (Butt) Joint



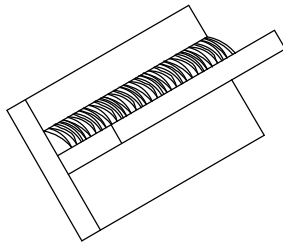
Groove (Butt) Joint



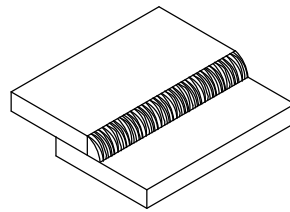
Lap Joint



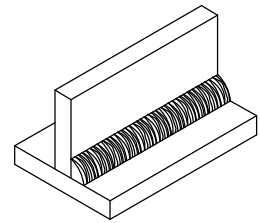
Tee Joint



Lap Joint



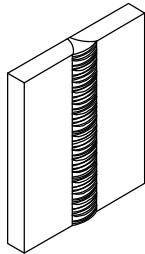
Tee Joint



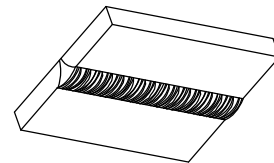
**Flat Position Welds**

**Horizontal Position Welds**

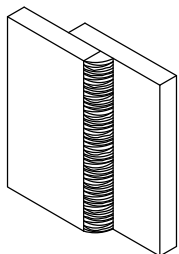
Groove (Butt) Joint



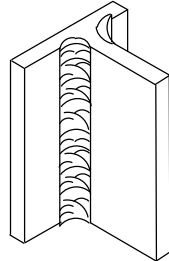
Groove (Butt) Joint



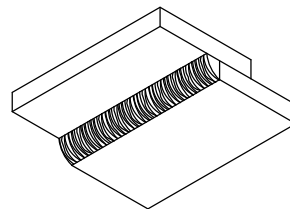
Lap Joint



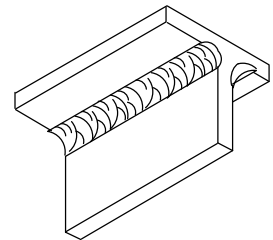
Tee Joint



Lap Joint



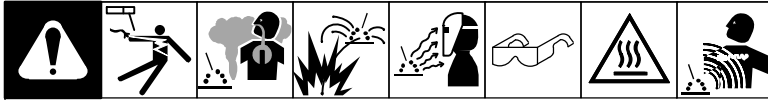
Tee Joint



**Vertical Position Welds**

**Overhead Position Welds**

### 3-11. Welding Groove (Butt) Joints



#### Types Of Groove (Butt) Joint Welds

##### 1 Tack Welds

Prevent butt joint distortion by tack welding the materials in position before final weld.

Workpiece distortion occurs when heat is applied locally to a joint. One side of a metal plate will "curl" up toward the weld. Distortion will also cause the edges of a butt joint to pull together ahead of the electrode as the weld cools.

##### 2 Square Groove Weld

##### 3 Single V-Groove Weld

##### 4 Double V-Groove Weld

Materials up to 3/16 in. (5 mm) thick can often be welded without special preparation using the square groove weld. However, when welding thicker materials it may be necessary to prepare the edges (V-groove) of butt joints to ensure good welds.

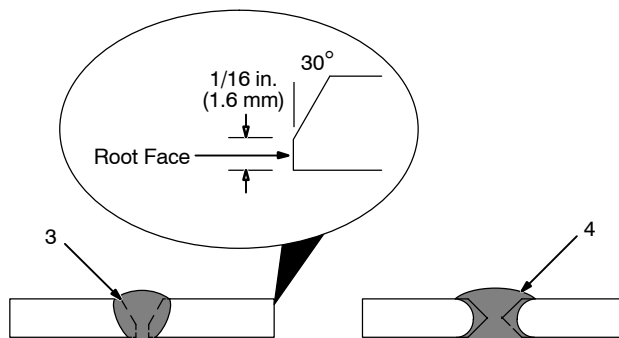
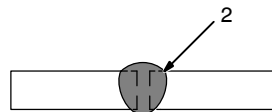
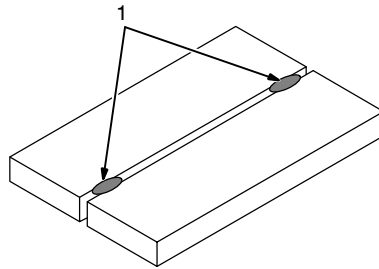
The single or double V-groove weld is good for materials 3/16 – 3/4 in. (5-19 mm) thick. Generally, the single V-groove is used on materials up to 3/4 in. (19 mm) thick and when, regardless of thickness, you can weld from one side only. Create a 30 degree bevel with oxyacetylene or plasma cutting equipment. Remove scale from material after cutting. A grinder can also be used to prepare bevels.

#### Groove (Butt) Joint Training Procedure

Practice welding butt joints on 1/8 in. (4 mm) or thicker material. (Avoid thinner materials since they require greater skill.) Separate the squared edges of the material about 1/16 in. (1.6 mm) and make a butt weld all the way through with a 1/8 in. electrode. (You may need to adjust the weld current and travel speed to obtain the desired weld.) Perform a similar exercise on 1/4 in. (6 mm) material, depositing a bead on each side of the joint and fusing one to the another (no bevel needed).

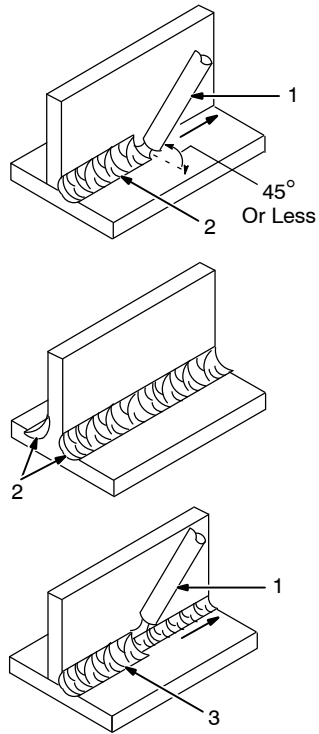
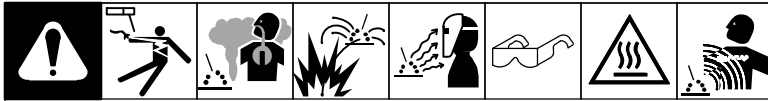
Practice making a single V-groove weld on 1/4 in. (6 mm) plate beveled 30°. Start with a 1/8 in. electrode for the first bead and finish with a 5/32 in. (4 mm) electrode. Be sure to penetrate about 1/32 in. (1 mm) beyond the bottom of the "V" or root. Perform a similar exercise on thicker materials. Generally, deposit a bead for each 1/8 in. (3mm) of material thickness, cleaning the joint between layers. On heavier plates, it may be necessary to weave the top layers to fill the groove.

After completing the practice welds, test them as described in Section 3-18.





### 3-12. Welding Tee Joints



- 1 Electrode
- 2 Fillet Weld

Keep arc short and move at definite rate of speed. Hold electrode as shown to provide fusion into the corner. Square edge of the weld surface.

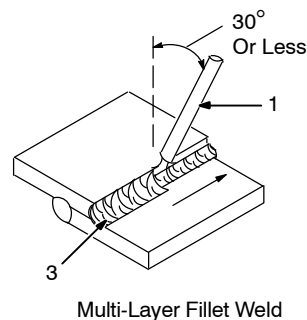
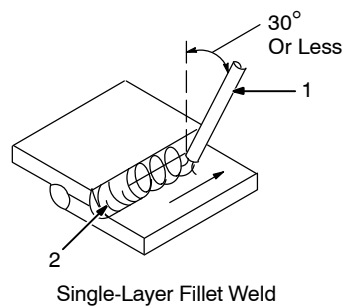
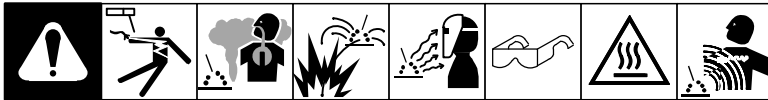
For maximum strength weld both sides of upright section.

- 3 Multi-Layer Deposits

Weld a second layer when a heavier fillet is needed. Use any of the weaving patterns shown in Section 3-6. Remove slag before making another weld pass.

S-0060 / S-0058-A / S-0061

### 3-13. Welding Lap Joints



- 1 Electrode
- 2 Single-Layer Fillet Weld

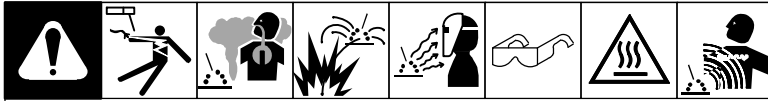
Move electrode in circular motion.

- 3 Multi-Layer Fillet Weld

Weld a second layer when a heavier fillet is needed. Remove slag before making another weld pass. Weld both sides of joint for maximum strength.

S-0063 / S-0064

### 3-14. Welding Horizontal Beads And Groove (Butt) Joints



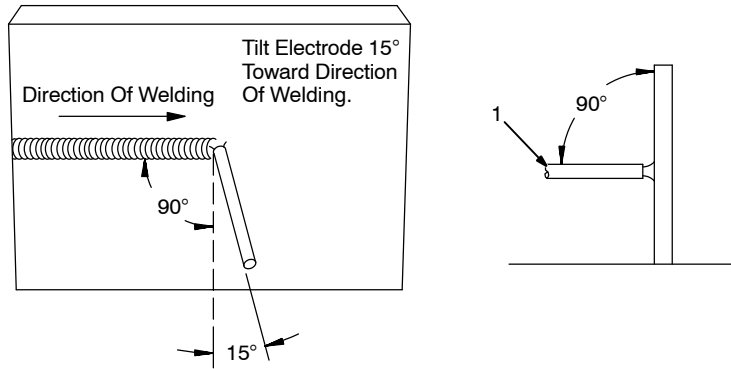
☞ When welding horizontally, gravity may distort the molten metal.

☞ This technique is not suitable for all electrodes.

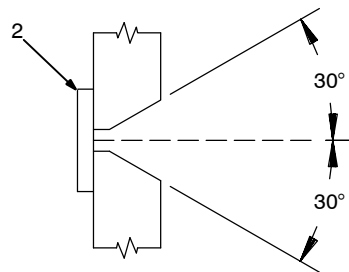
- 1 Electrode
- 2 Backing Strip

Bevel edges if warranted by material thickness (see Section 3-11). Tack weld a backing strip to the plates to make the first weld pass (root pass) easier.

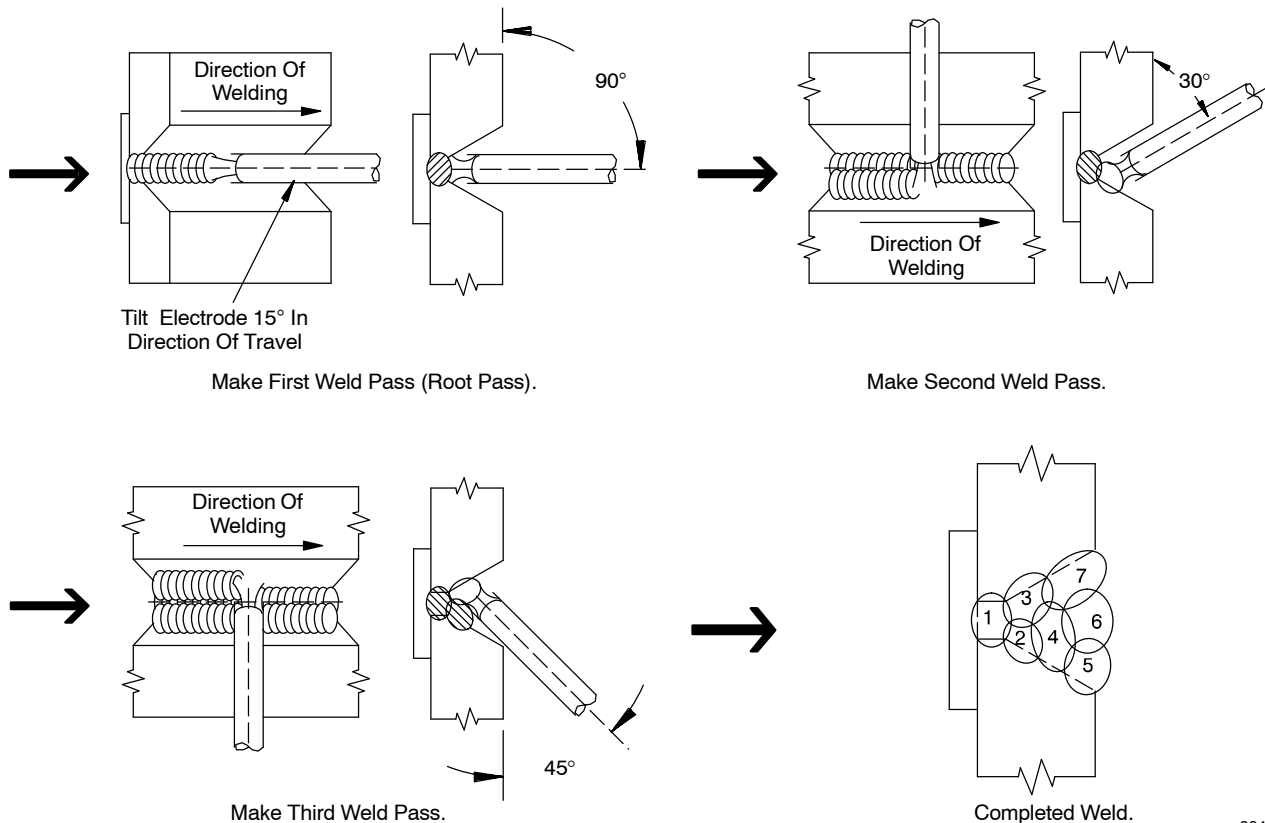
#### Single Pass Bead Weld



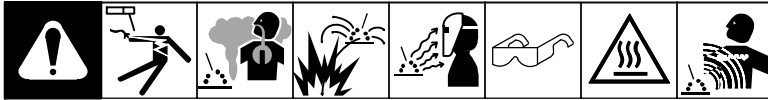
#### Single Pass Horizontal Groove (Butt) Joint Weld Or First Pass Of Multi-Layer Deposit



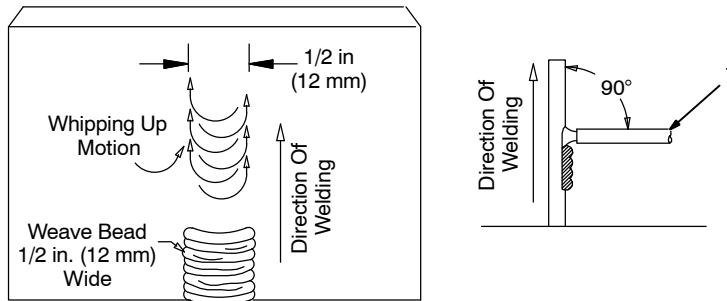
Bevel Material If Necessary (See Section 3-11).



### 3-15. Welding Vertical Beads And Groove (Butt) Joints



#### Single Pass Bead Weld



☞ When welding vertically, gravity may distort the molten metal.

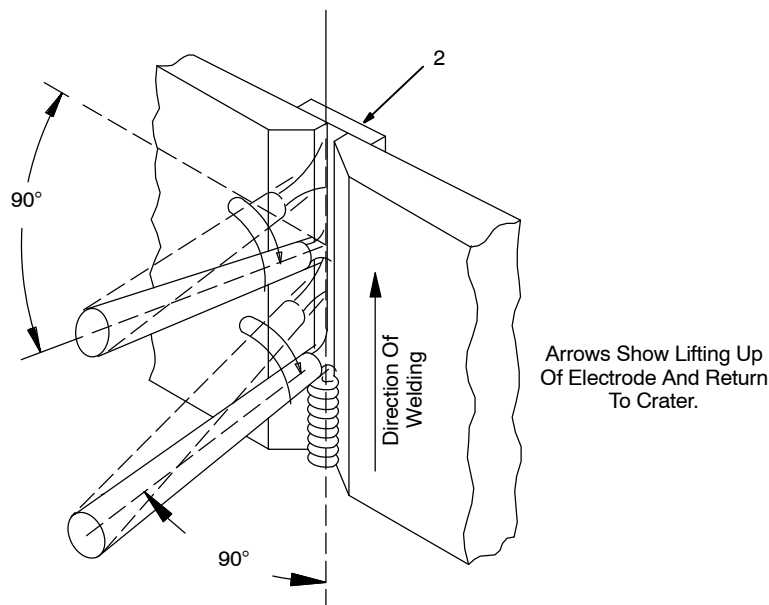
☞ This technique is not suitable for all electrodes.

- 1 Electrode
- 2 Backing Strip

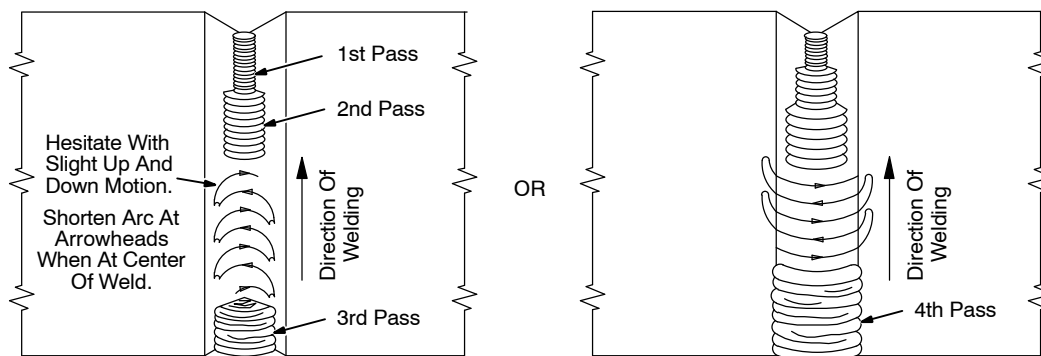
Weld vertically by carrying the weld upward or starting at the top and welding down. Welding upward is easier and is shown in these illustrations.

Bevel edges if warranted by material thickness (see Section 3-11). Tack weld a backing strip to the plates to make the first weld pass (root pass) easier.

#### Single Pass Vertical Groove (Butt) Joint Weld Or First Pass Of Multi-Layer Deposit



Arrows Show Lifting Up Of Electrode And Return To Crater.



Vertical Groove (Butt) Joint Weld Subsequent Layers

### 3-16. Welding Vertical Tee Joints And Lap Joints



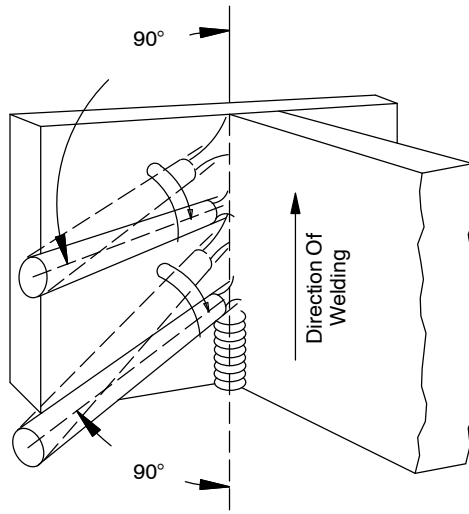
☞ When welding vertically, gravity may distort the molten metal.

☞ This technique is not suitable for all electrodes.

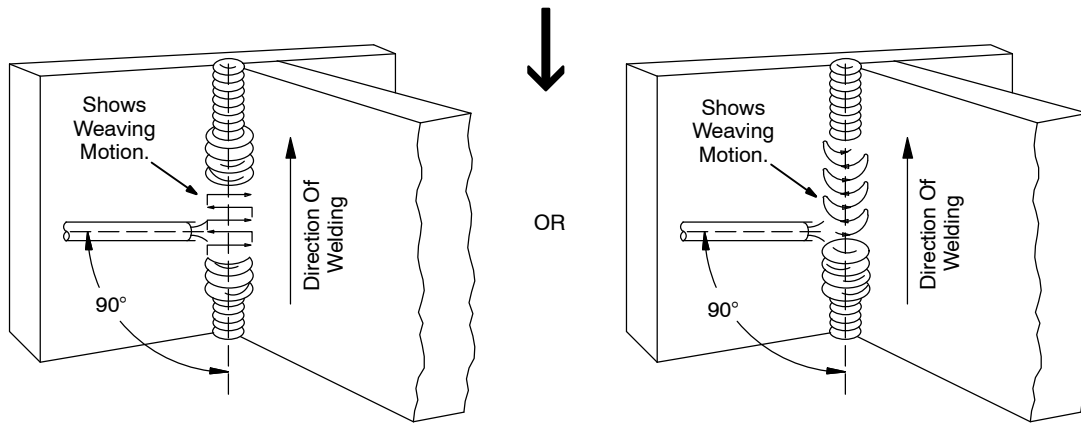
For maximum strength, weld both sides of joint.

#### Tee Joint Weld

Arrows Show Lifting Up Of Electrode And Return To Crater.

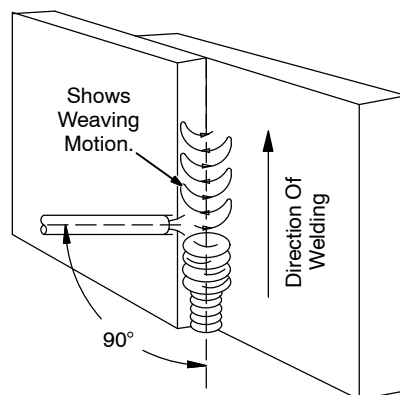


First Weld Pass

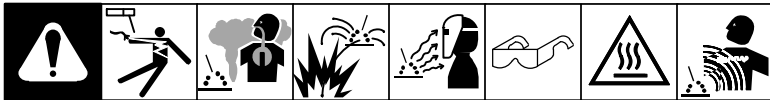


Subsequent Weld Passes

#### Lap Joint Weld



### 3-17. Welding Overhead Groove (Butt) Joints And Tee Joints



☞ When welding overhead, gravity may distort the molten metal.

☞ This technique is not suitable for all electrodes.

- 1 Electrode
- 2 Backing Strip

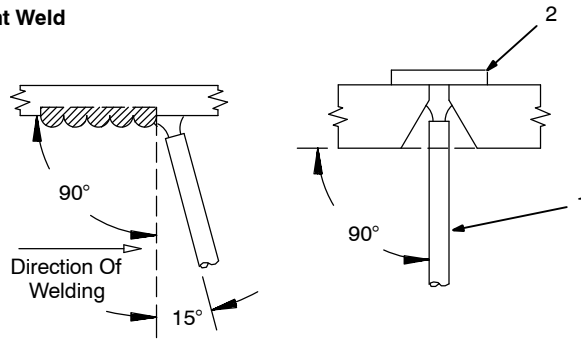
Welding overhead is the most difficult welding skill to master.

When welding overhead, use a welding motion that draws arc out and slightly away from the crater to allow weld puddle to solidify.

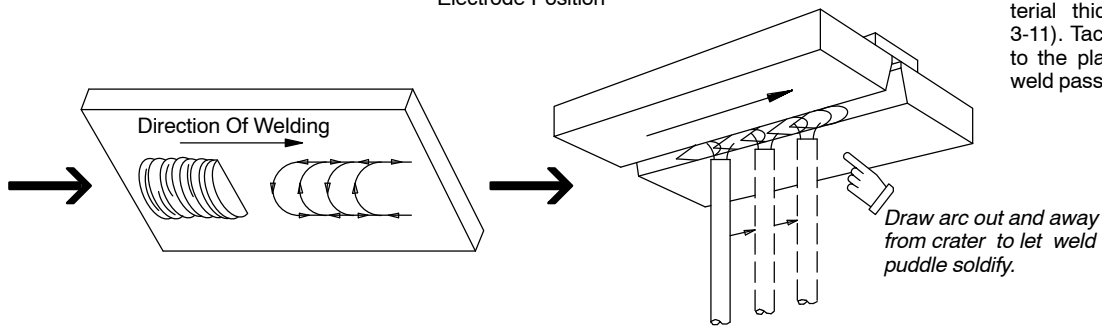
When weaving is necessary, use the pattern shown.

Bevel edges if warranted by material thickness (see Section 3-11). Tack weld a backing strip to the plates to make the first weld pass (root pass) easier.

#### Groove (Butt) Joint Weld

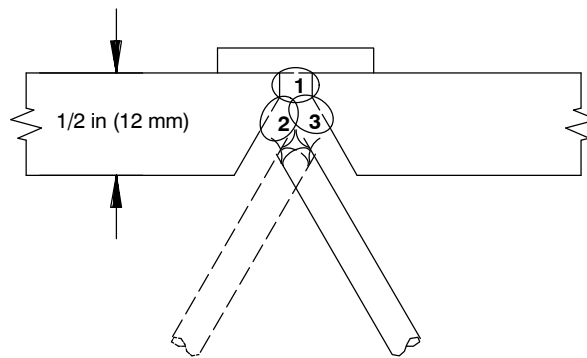


Electrode Position



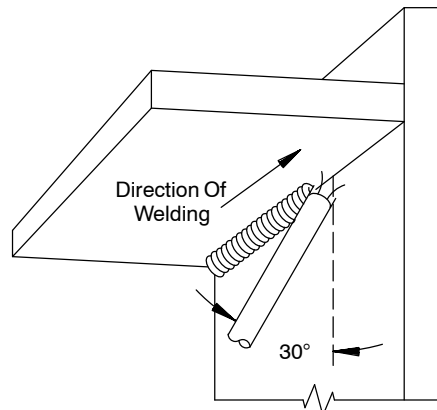
Welding Patterns

Overhead Welding Technique

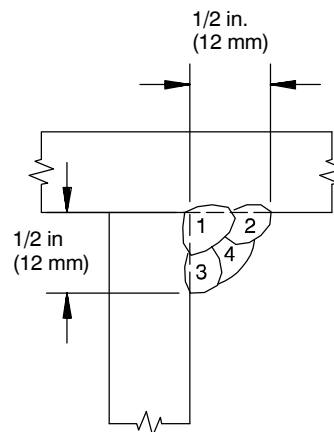


Sequence Of Multiple Weld Passes

#### Tee Joint Weld

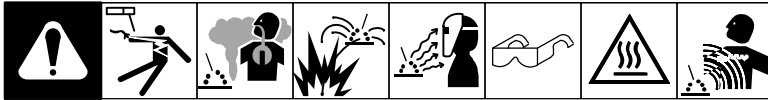


First Weld Pass



Subsequent Weld Passes

### 3-18. Weld Test



- 1 Vise
- 2 Weld Joint
- 3 Hammer

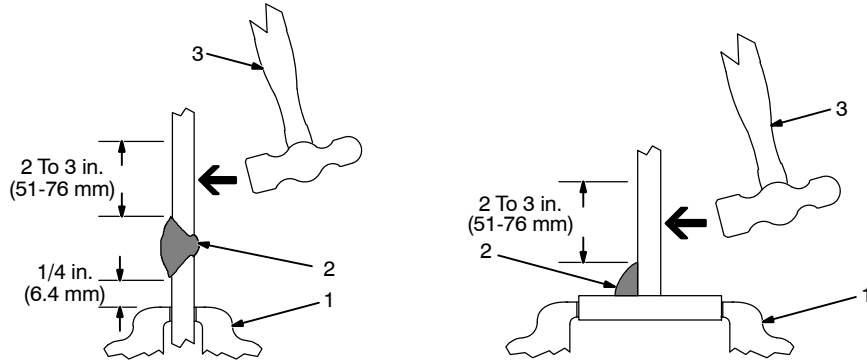
Strike the weld joint in the direction shown. A good weld bends over but does not break.

If the weld breaks, examine it to determine the cause.

If the weld is porous (many holes), the arc length was probably too long.

If the weld contains bits of slag, the arc may have been too long or the electrode was moved incorrectly which allowed molten slag to be trapped in the weld. This may happen on a V-groove joint made in several layers and calls for additional cleaning between layers.

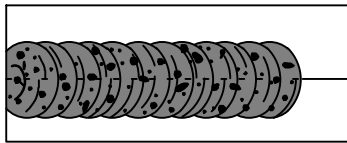
If the original beveled surface is visible the material was not fully melted which is often caused by insufficient heat or too fast a travel speed.



S-0057-B

## SECTION 4 – WELDING TROUBLESHOOTING

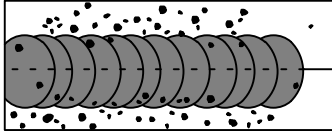
### 4-1. Porosity



Porosity – small cavities or holes resulting from gas pockets in weld metal.

Possible Causes	Corrective Actions
Arc length too long.	Reduce arc length.
Workpiece dirty.	Remove all grease, oil, moisture, rust, paint, coatings, slag, and dirt from work surface before welding.
Damp electrode.	Use dry electrode.

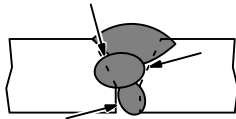
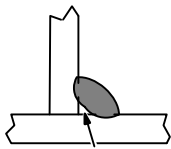
## 4-2. Excessive Spatter



Excessive Spatter – scattering of molten metal particles that cool to solid form near weld bead.

Possible Causes	Corrective Actions
Amperage too high for electrode.	Decrease amperage or select larger electrode.
Arc length too long or voltage too high.	Reduce arc length or voltage.

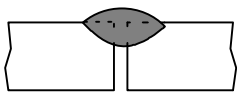
## 4-3. Incomplete Fusion



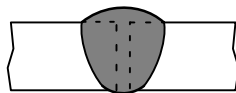
Incomplete Fusion – failure of weld metal to fuse completely with base metal or a preceding weld bead.

Possible Causes	Corrective Actions
Insufficient heat input.	Increase amperage. Select larger electrode and increase amperage.
Improper welding technique.	Place stringer bead in proper location(s) at joint during welding. Adjust work angle or widen groove to access bottom during welding. Momentarily hold arc on groove side walls when using weaving technique. Keep arc on leading edge of weld puddle.
Workpiece dirty.	Remove all grease, oil, moisture, rust, paint, coatings, slag, and dirt from work surface before welding.

## 4-4. Lack Of Penetration



Lack of Penetration

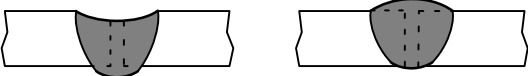


Good Penetration

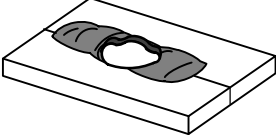
Lack Of Penetration – shallow fusion between weld metal and base metal.

Possible Causes	Corrective Actions
Improper joint preparation.	Material too thick. Joint preparation and design must provide access to bottom of groove.
Improper weld technique.	Keep arc on leading edge of weld puddle. Reduce travel speed.
Insufficient heat input.	Increase amperage. Select larger electrode and increase amperage.

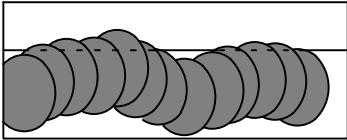
### 4-5. Excessive Penetration

		<p>Excessive Penetration – weld metal melting through base metal and hanging underneath weld.</p>
<p>Excessive Penetration</p>	<p>Good Penetration</p>	
<p><b>Possible Causes</b></p>	<p><b>Corrective Actions</b></p>	
<p>Excessive heat input.</p>	<p>Select lower amperage. Use smaller electrode.</p>	
<p>Improper weld technique.</p>	<p>Adjust travel speed.</p>	

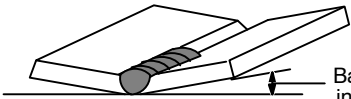
### 4-6. Burn-Through

		<p>Burn-Through – weld metal melting completely through base metal resulting in holes where no metal remains.</p>
<p><b>Possible Causes</b></p>	<p><b>Corrective Actions</b></p>	
<p>Excessive heat input.</p>	<p>Select lower amperage. Use smaller electrode. Increase and/or maintain steady travel speed.</p>	

### 4-7. Waviness Of Bead

		<p>Waviness Of Bead – weld metal that is not parallel and does not cover joint formed by base metal.</p>
<p><b>Possible Causes</b></p>	<p><b>Corrective Actions</b></p>	
<p>Unsteady hand.</p>	<p>Use two hands. Practice technique.</p>	

### 4-8. Distortion

		<p>Distortion – contraction of weld metal during welding that forces base metal to move.</p>
<p>Base metal moves in the direction of the weld bead.</p>		
<p><b>Possible Causes</b></p>	<p><b>Corrective Actions</b></p>	
<p>Excessive heat input.</p>	<p>Use restraint (clamp) to hold base metal in position. Make tack welds along joint before starting welding operation. Predict anticipated weld distortion and precamber base metal. Select lower amperage for electrode. Increase travel speed. Weld in small segments and allow cooling between welds.</p>	









**Miller Electric Mfg. LLC**

An Illinois Tool Works Company  
1635 West Spencer Street  
Appleton, WI 54914 USA

**For Assistance:**  
Call 1-800-332-3281

