



Learning Materials

The following learning materials, developed by The Lincoln Electric Company, were used in the IMAC – Welding Level II training course. The materials are available for download at The Lincoln Electric Company website listed below.

**The Lincoln Electric Company
22801 St. Clair Ave.
Cleveland, OH 44117**

Website:

<http://www.lincolnelectric.com/knowledge/training/weldcurriculum.asp>

IMAC Welding Courses:

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A Lincoln Electric welding machine is shown in the upper center, with bright orange sparks erupting from its base. The machine is positioned on a dark, cracked metal surface. The background is a dark, textured metal plate with visible rivets. A red horizontal line runs across the middle of the image, and a red vertical line runs down the right side. The Lincoln Electric logo is on the left, and the word 'WELDING' is in large white letters in the center. Below 'WELDING' is the tagline 'connects your world'. In the bottom right, the text 'SMAW (Stick Welding)' is written in white, with a stylized double arrow graphic below it.

LINCOLN[®]
ELECTRIC

WELDING

connects your world

SMAW
(Stick Welding)

SMAW Unit Topics

- During this overview, we will discuss the following topics:
 - *Safety*
 - *SMAW Basics*
 - *Equipment Set-Up*
 - *Welding Variables*
 - *Process Advantages and Limitations*
 - *AWS Connection*
 - *National Academic Standards Connection*



The SMAW process is great for maintenance and repair work!

Unit Objectives

- Upon successful completion of the SMAW Unit of Study, you will have learned to:
 - *Properly protect yourself and others while welding*
 - *Set up and operate SMAW equipment*
 - *Strike and maintain an arc*
 - *Make welds in four positions using different electrodes*
 - *Understand a weld inspection process*
 - *Apply the AWS electrode classification system*
 - *Take the next step to becoming a certified welder*



Most structural steel welders are required to be certified



SMAW Safety



- 'SMAW Safety' is supplemental and does not replace the information found in 'Arc Welding Basics'
- Understand and follow all safety precautions listed in 'Safety in Welding, Cutting, and Allied Processes' (ANSI Z49.1) and Arc Welding Safety (E205)
- Understand and follow all warning labels found:
 - *On welding equipment*
 - *With all consumable packaging*
 - *Within instruction manuals*
- Read Material Safety Data Sheets (MSDS)



If you ever have a question about your safety or those around you, PLEASE ASK YOUR INSTRUCTOR!

- **Fumes and Gases** can be dangerous
 - *Keep your head out of the fumes*
 - *Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area*
 - *The SMAW process can withstand wind and exhaust near the arc from ventilation equipment*
- **Electric Shock** can kill – to receive a shock your body must touch the electrode and work or ground at the same time
 - *Do not touch the electrode or metal parts of the electrode holder with skin or wet clothing*
 - *Keep dry insulation between your body and the metal being welded or ground*
- **Arc Rays** can injure eyes and skin - Choose correct filter shade (See chart below)

Table 1
Guide for Shade Numbers

Operation	Electrode Size 1/32 in. (mm)	Arc Current (A)	Minimum Protective Shade	Suggested* Shade No. (Comfort)
Shielded metal arc welding	Less than 3 (2.5)	Less than 60	7	
	3—5 (2.5—4)	60—160	8	10
	5—8 (4—6.4)	160—250	10	12
	More than 8 (6.4)	250—550	11	14

*As a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.

**These values apply where the actual arc is clearly seen. Experience has shown that lighter filters may be used when the arc is hidden by the workpiece.

** Information taken from ANSI Z49.1:2005**

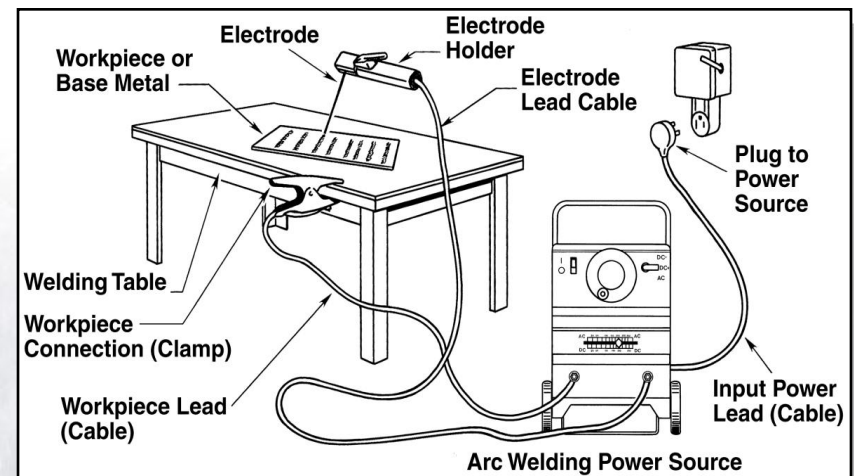


SMAW Principles



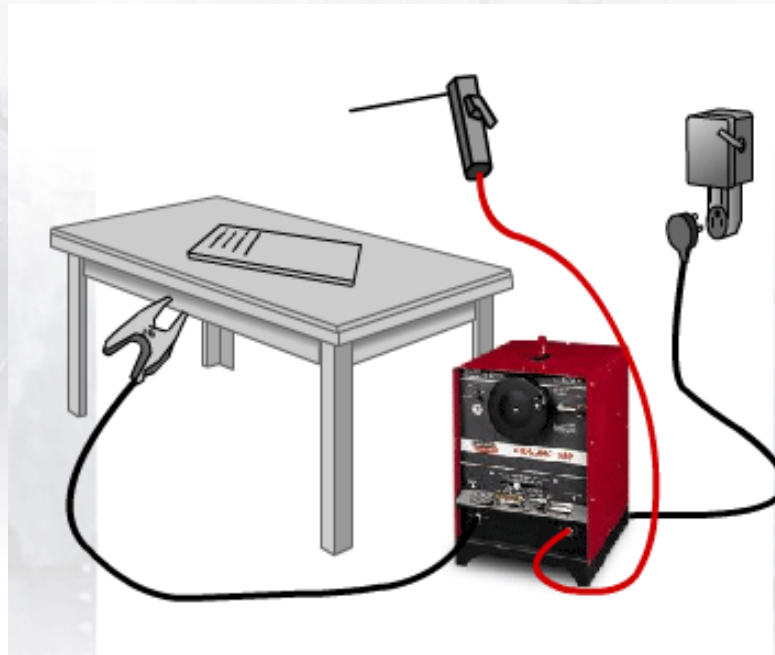
SMAW Principles

- The American Welding Society defines SMAW as Shielded Metal Arc Welding
- SMAW:
 - *Is commonly known as 'Stick' welding or manual arc welding*
 - *Is the most widely used arc welding process in the world*
 - *Can be used to weld most common metals and alloys*

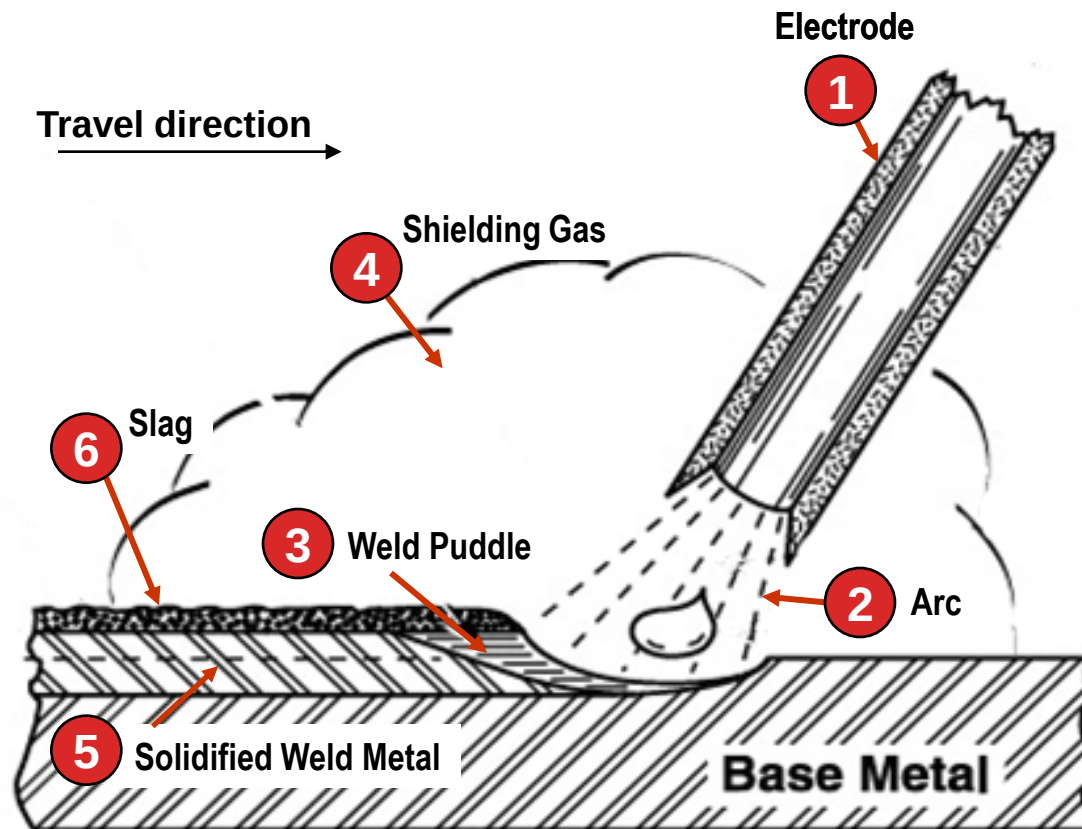


SMAW Welding Circuit

- Current flows through the electrode cable, to the electrode holder, through the electrode, and across the arc
- On the work side of the arc, the current flows through the base material to the work clamp and back to the welding machine

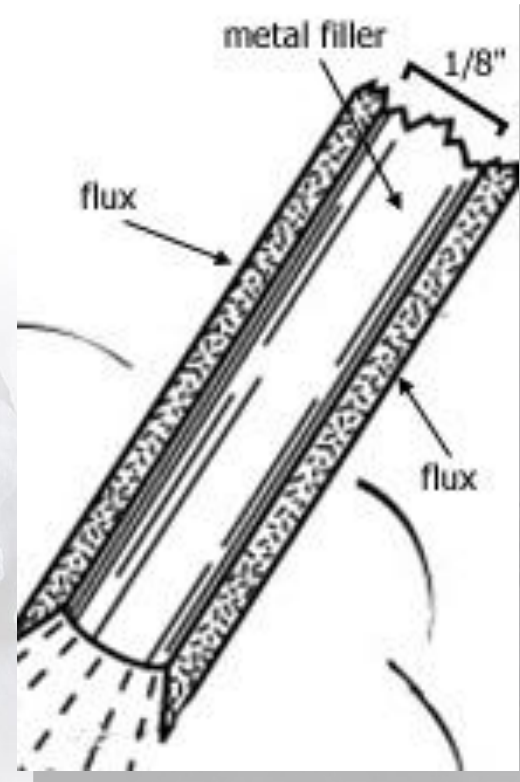


Let's take a little closer look at the SMAW process...



1- The Electrode

- Is a consumable - it gets melted during the welding process
- Is composed of two parts
 - *Core Rod (Metal Filler)*
 - Carries welding current
 - Becomes part of the weld
 - *Flux Coating*
 - Produces a shielding gas
 - Can provide additional filler
 - Forms a slag



2- The Arc



Can you identify the weld joint and position being used?

- An arc occurs when the electrode comes in contact with the work-piece and completes the circuit ... like turning on a light!
- The electric arc is established in the space between the end of the electrode and the work
- The arc reaches temperatures of 10,000 F which melts the electrode and base material

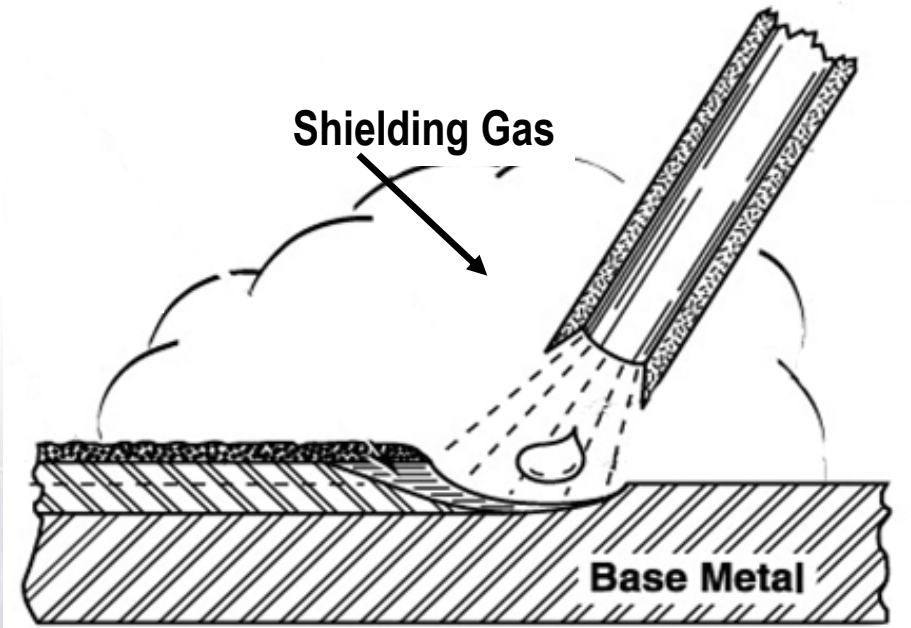
3- Weld Puddle

- As the core rod, flux coating, and work pieces heat up and melt, they form a pool of molten material called a weld puddle
- The weld puddle is what a welder watches and manipulates while welding



1/8" E6013 at
125 Amps AC

4- Shielding Gas



The shielding gas protects the molten puddle from the atmosphere while stabilizing the arc

- A shielding gas is formed when the flux coating melts.
- This protects the weld puddle from the atmosphere preventing contamination during the molten state

5- Solidified Weld Metal

- As the molten weld puddle solidifies, it forms a joint or connection between two pieces of base material
- When done properly on steel, it results in a weld stronger than the surrounding base metal



- Slag is a combination of the flux coating and impurities from the base metal that float to the surface of the weld.
- Slag quickly solidifies to form a solid coating
- The slag also slows the cooling rate of the weld
- The slag can be chipped away and cleaned with a wire brush when hard



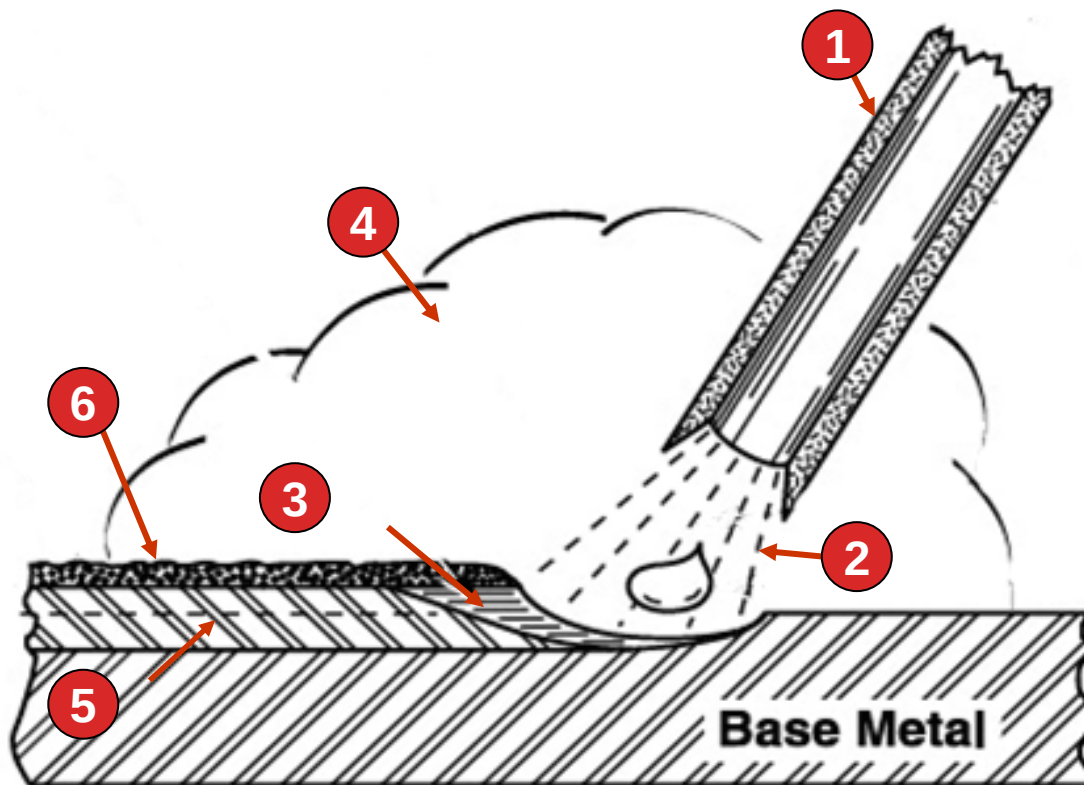
This welder chips the slag off of a weld during the repair of railroad tracks



Application Activity



Let's review the SMW process ...



- 1 = _____
- 2 = _____
- 3 = _____
- 4 = _____
- 5 = _____
- 6 = _____

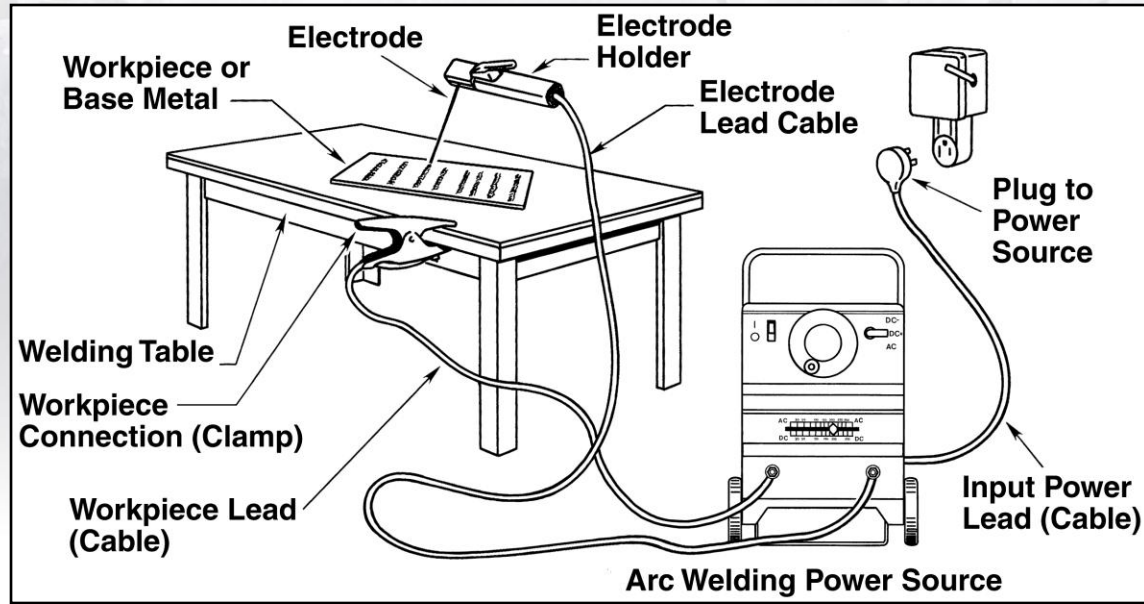


Equipment Set Up



SMAW Equipment Set Up

1. Turn power supply on
2. Connect work clamp
3. Select electrode
 - a. Type
 - b. Diameter
4. Adjust output
 - a. Polarity
 - b. Amperage
6. Insert electrode into electrode holder



SMAW Process Variables

- Settings on the machine
 - *Polarity : AC, DC+, DC-*
 - *Amperage Output*
- Operator Controlled Variables
 - *Work Angle*
 - *Travel Angle*
 - *Arc Length*
 - *Travel Speed*



A straight AC machine will not have a polarity switch like this AC/DC machine

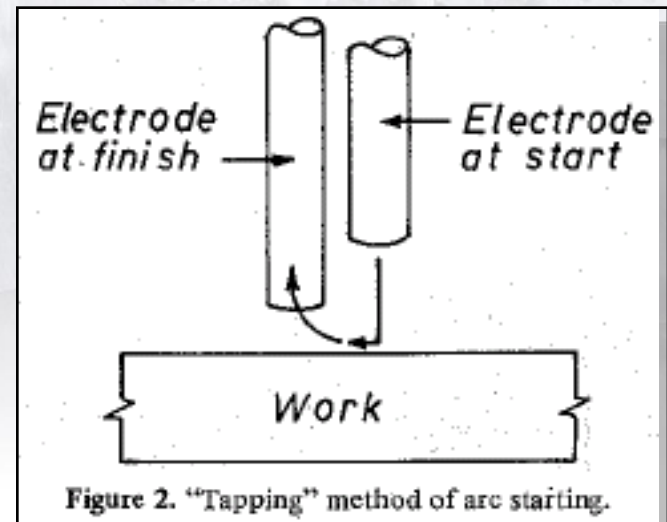
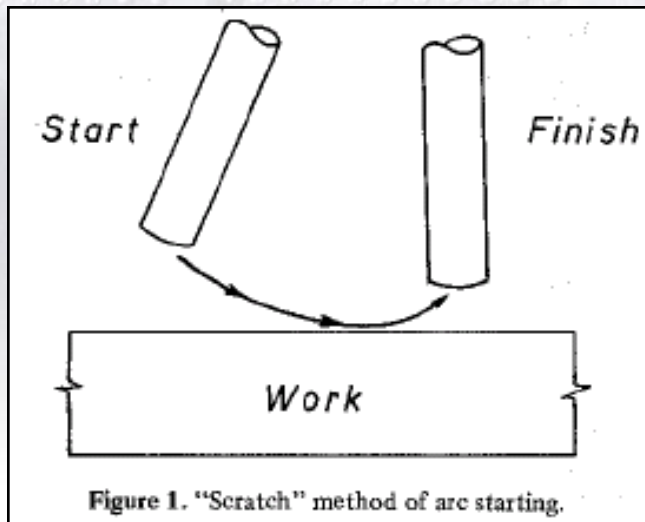


Striking an Arc and Making a Weld

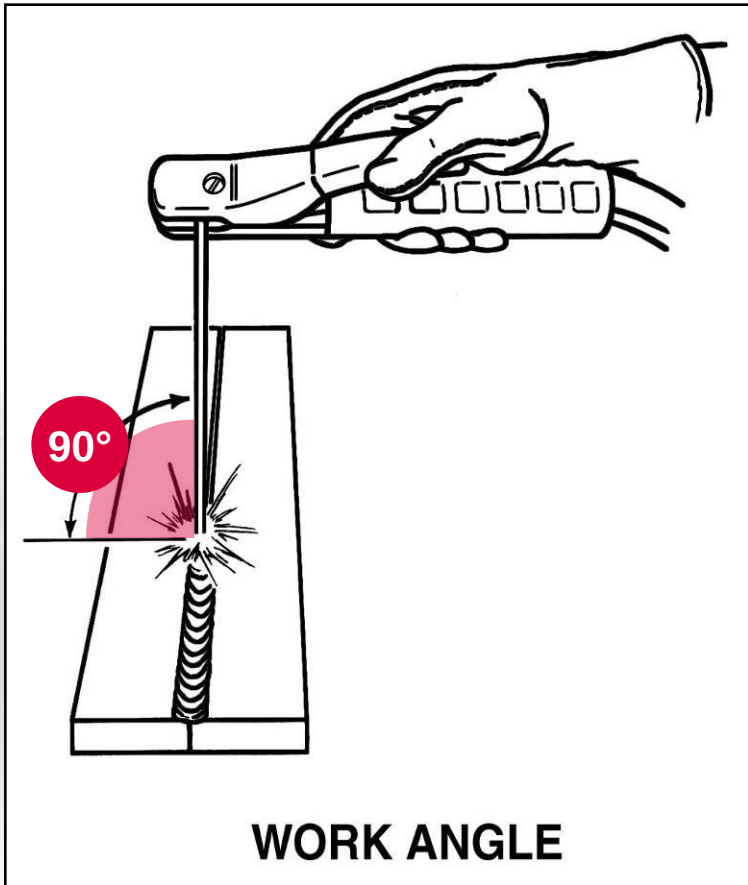


Striking an Arc

- To begin the SMAW Process, you must first strike an arc. This can be done using one of the following techniques:
 - *Scratch start* – scratch the electrode on the base metal like a match
 - *Tap Start* – tap the rod against the base metal

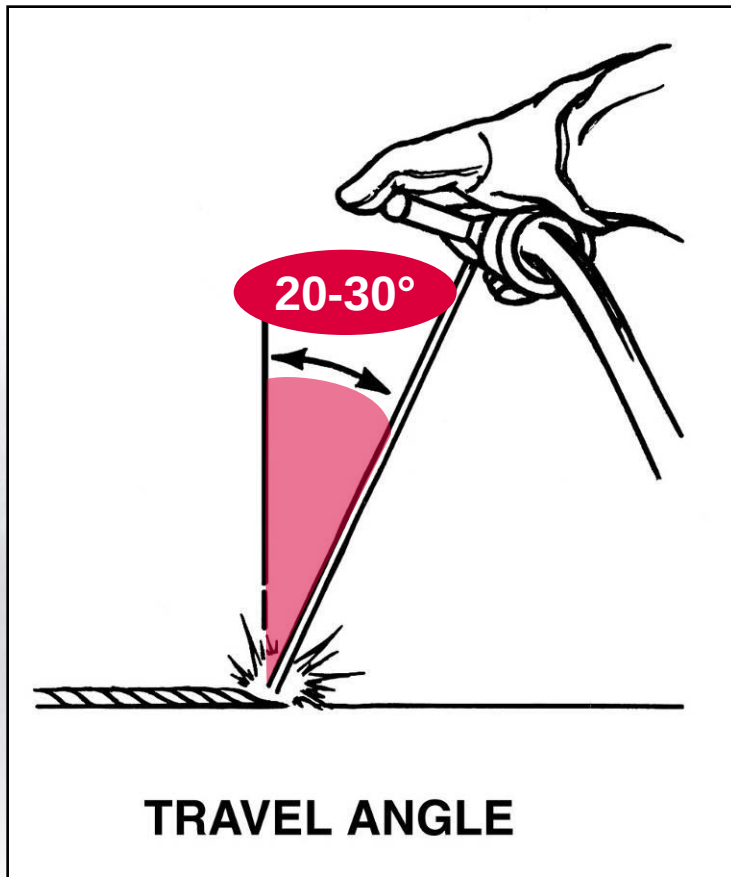


Work Angle



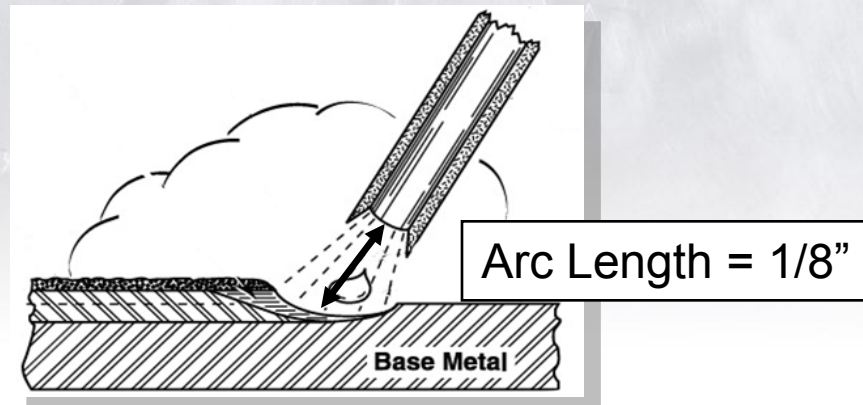
- The work angle is the angle between the electrode and the work as depicted on the left
- Work angles can vary depending on the position the weld is being made in

Travel Angle



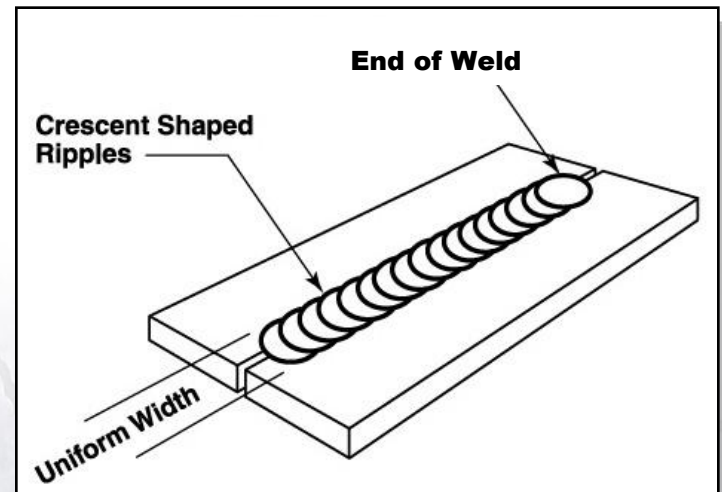
- Also commonly called Lead Angle
- The travel (lead) angle is the angle between the electrode and the plane perpendicular to the weld axis

- After striking the arc, maintain a $\frac{1}{8}$ " distance between the electrode and the workpiece
 - *If the arc length becomes too short, the electrode will get stuck to the workpiece or 'short out'*
 - *If the arc length becomes too long; spatter, undercut, and porosity can occur*



Travel Speed

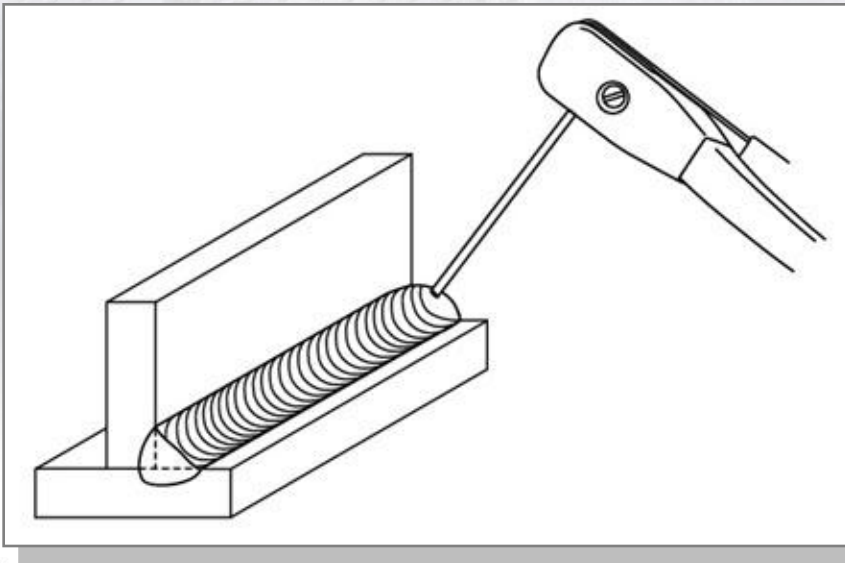
- The travel speed is the speed at which the electrode moves along the base material while welding
 - *Too fast of a travel speed results in a ropey or convex weld*
 - *Too slow of a travel speed results in a wide weld with an excessive metal deposit*



The travel speed impacts the shape of the bead.

Filling the Crater

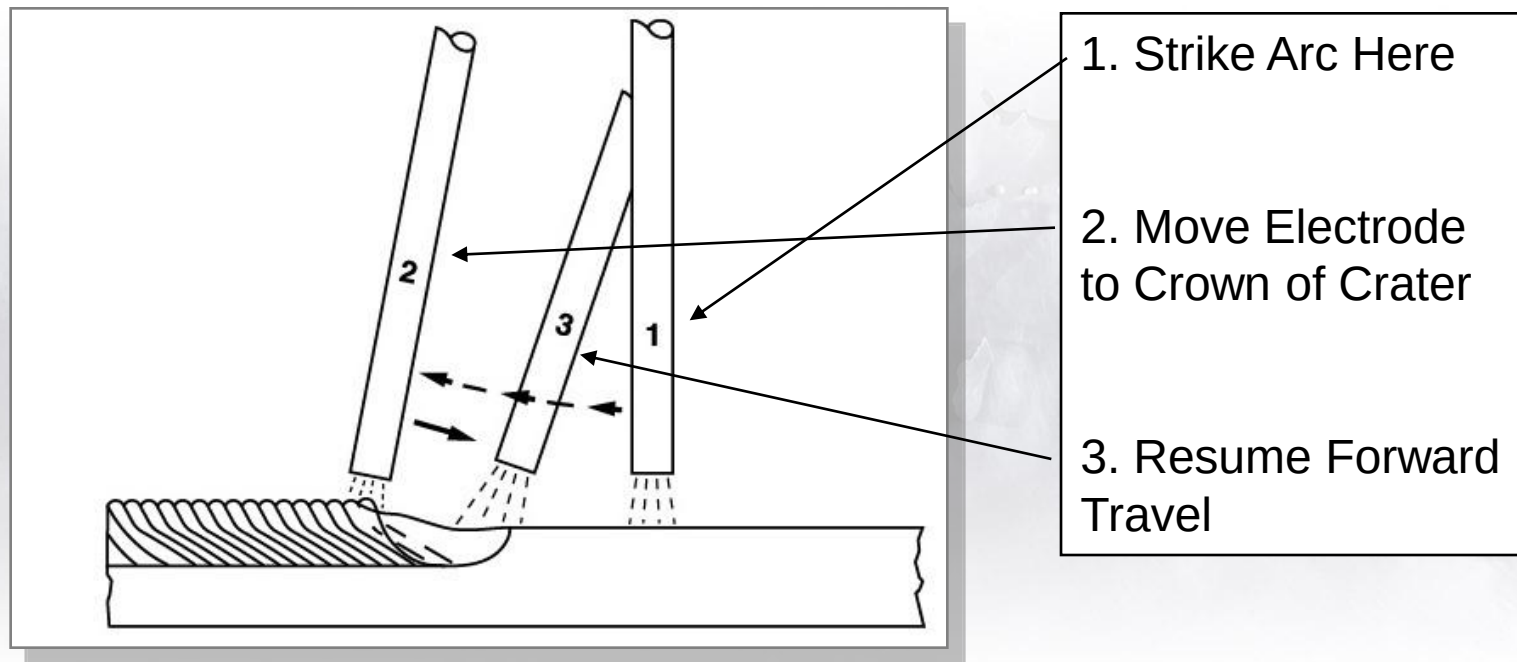
- At the end of the weld, the operator breaks the arc which creates a 'crater'
- Use a short pause or slight back step at the end of the weld to fill the crater
- Large craters can cause weld cracking



Back stepping is a short move in the opposite direction of weld travel

Restarting a Bead

- Here is the proper technique for restarting a weld:

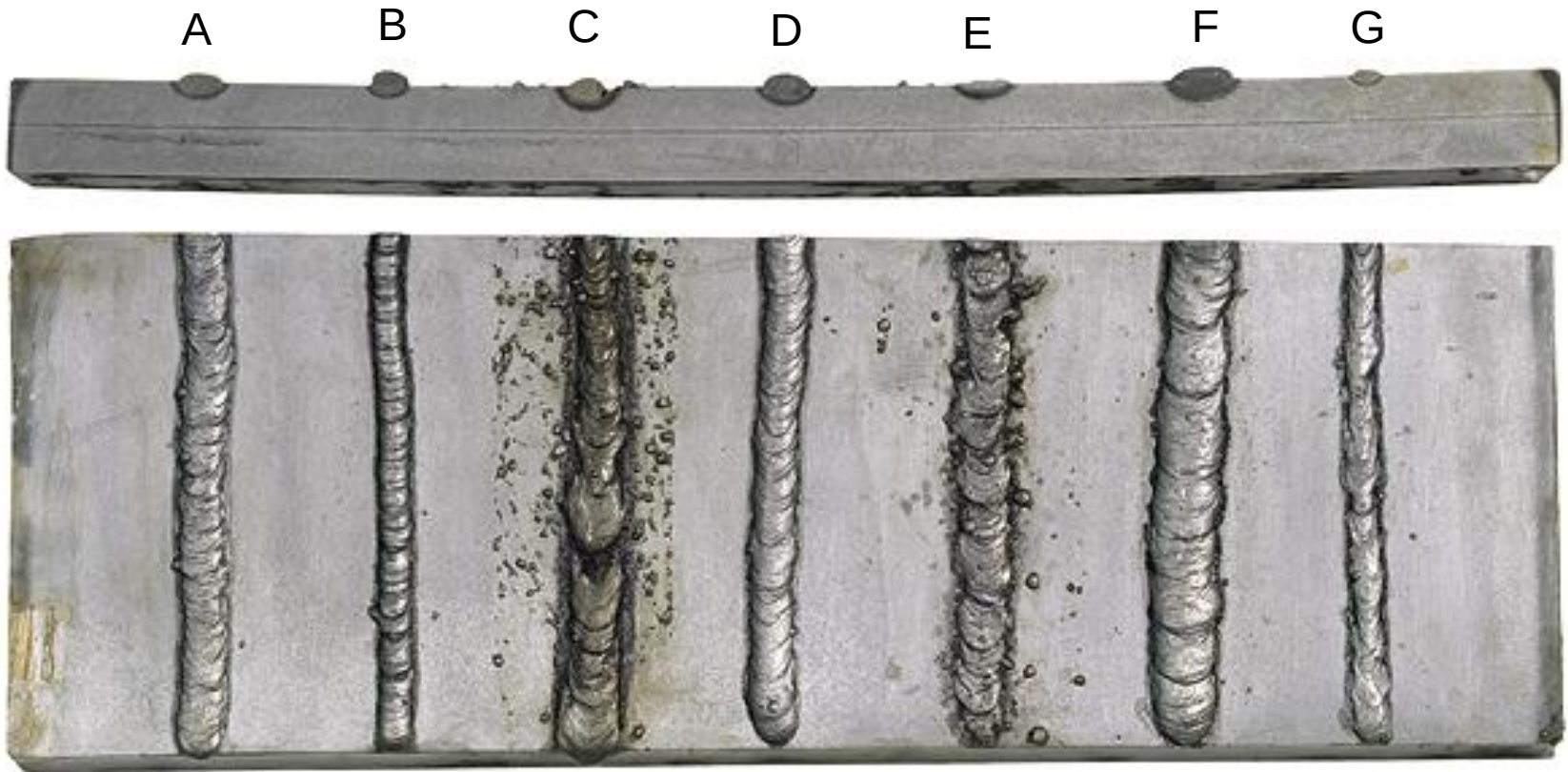




Troubleshooting Welds



Troubleshooting Welds



These welds were cut and etched with nitric acid to show penetration



SMAW Advantages and Limitations

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Advantages of SMAW

- Low initial cost
- Portable
- Easy to use outdoors
- All position capabilities
- Easy to change between many base materials



What safety precautions should be taken by these welders?

Limitations of SMAW

- Lower consumable efficiency
- Difficult to weld very thin materials
- Frequent restarts
- Lower operating factor
- Higher operator skill required for SMAW than some other processes



Building a barge in a large shipyard



AWS Classification of SMAW Electrodes



AWS Classification of SMAW Electrodes

E70XX

Electrode _____

Tensile in Ksi _____

Welding Position: _____

1 = All Position, 2 = Flat & Horizontal

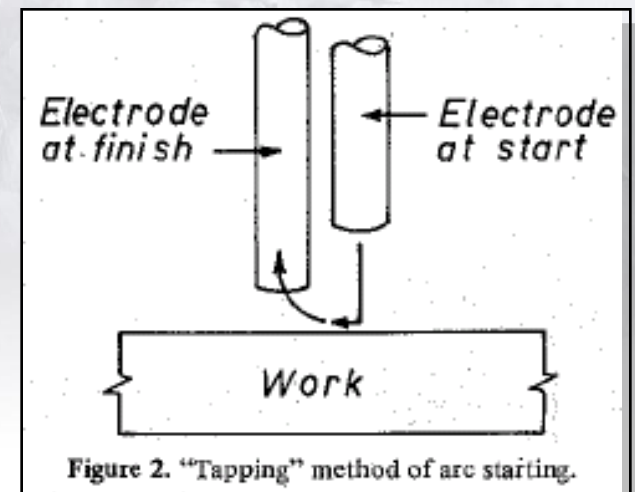
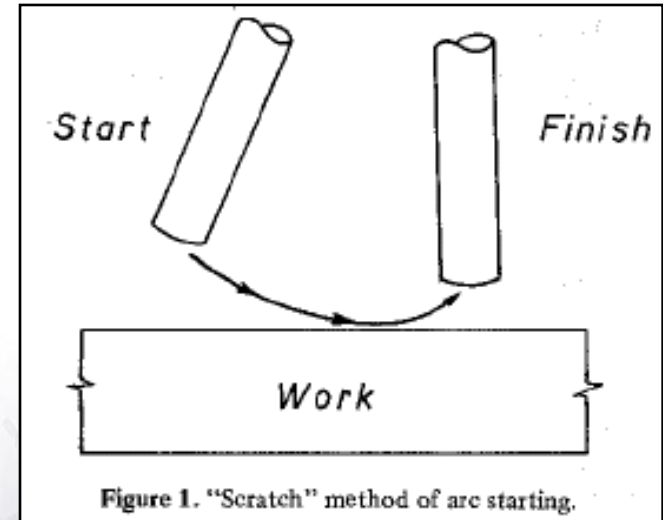
Type of Current and Coating _____



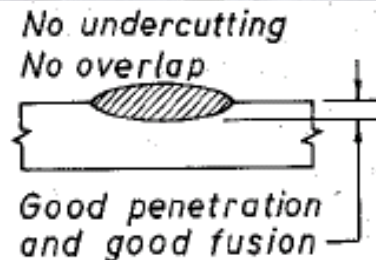
Lesson Plans



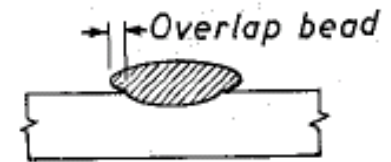
- Objective: Strike and establish an arc
- Equipment:
 - *Single Process* –
Constant Current Power Source
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate 1/8" or thicker*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



- Objective: To run a straight bead on flat plate and to fill the crater
- Equipment:
 - *Single Process -*
Constant Current Power Source
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate 3/16" or thicker*
 - *1/8" Fleetweld 37 (E6013)*

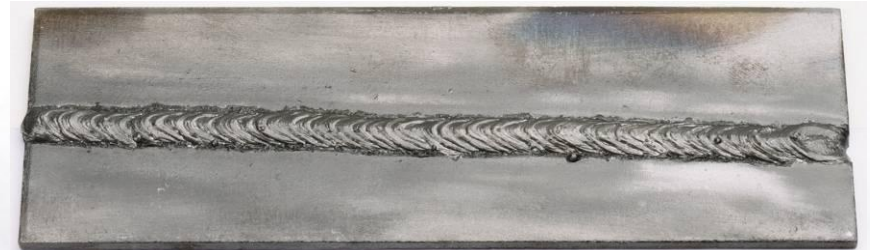


Good



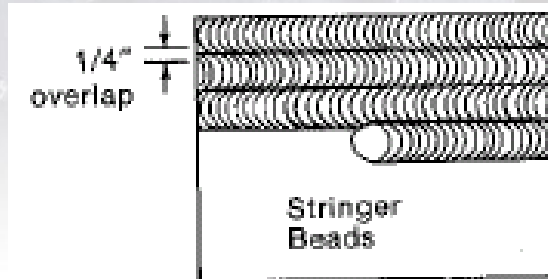
Poor

- Objective: To run a bead with the whip technique
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate 3/16" or thicker*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



SMAW Lesson #4

- Objective: To build a pad
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate 3/16" or thicker*
 - *1/8" Fleetweld 37 (E6013)*

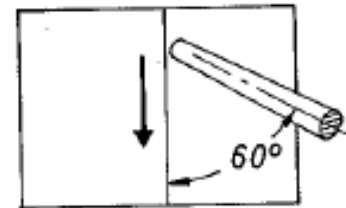
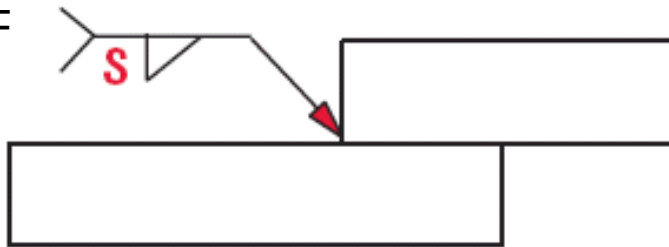


SMAW Lesson #5

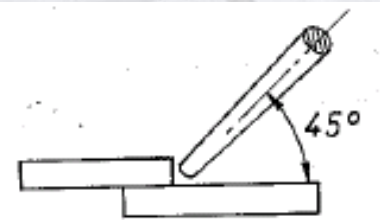
- Objective: To make a fillet weld on a lap joint in the horizontal position (AWS Position 2F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



2F

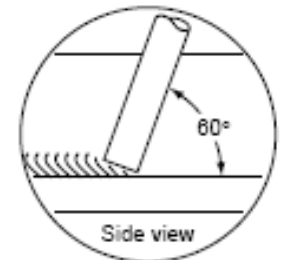
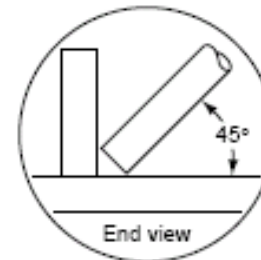
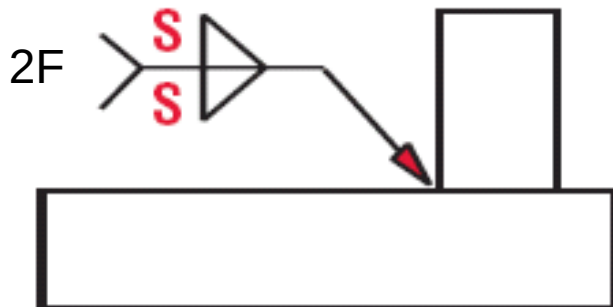


Top View

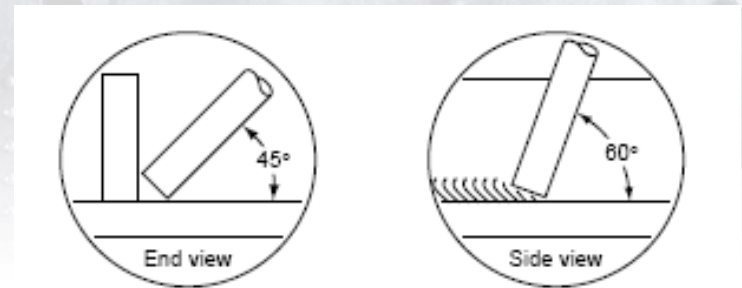
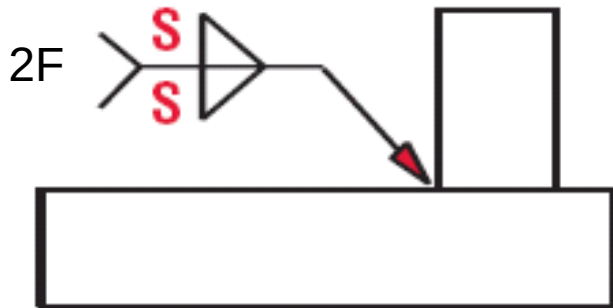


Side View

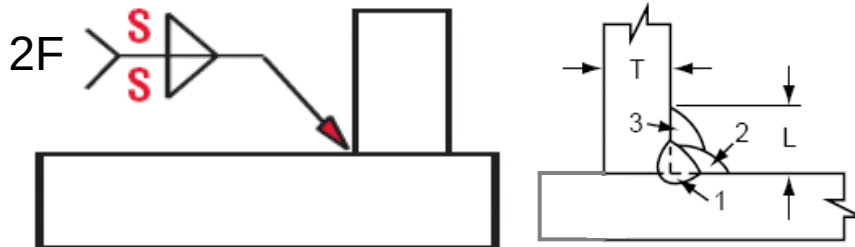
- Objective: To make a fillet weld on a tee joint in the horizontal position (AWS Position 2F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



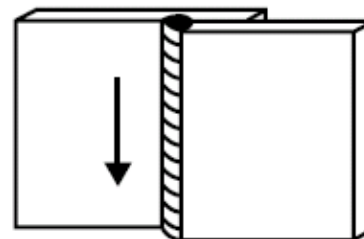
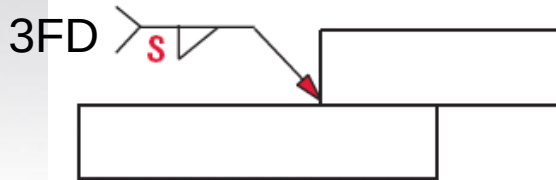
- Objective: To make a fillet weld on a tee joint in the horizontal position (AWS Position 2F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Excalibur 7018 (E7018) for DC or Lincoln 7018AC (E7018) for AC*



- Objective: To make a three pass fillet weld on a tee joint in the horizontal position (AWS Position 2F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate – 1/4"*
 - *1/8" Excalibur 7018 (E7018) for DC or Lincoln 7018AC (E7018) for AC*

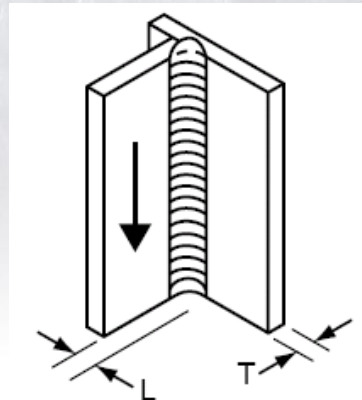
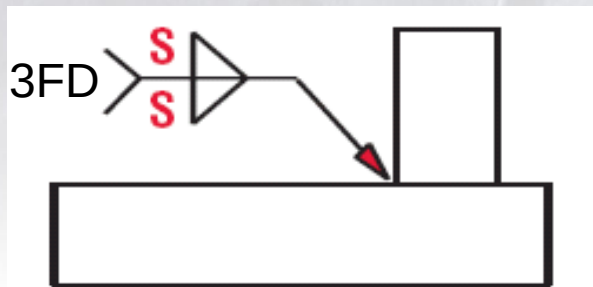


- Objective: To make a fillet weld on a lap joint in the vertical position welding down (AWS Position 3FD)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 37 (E6013)*

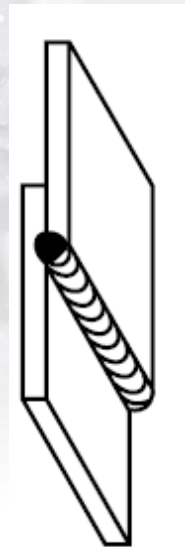
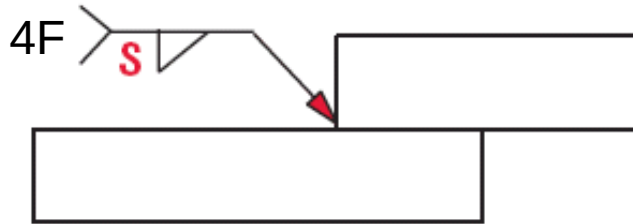


Vertical (welded down)

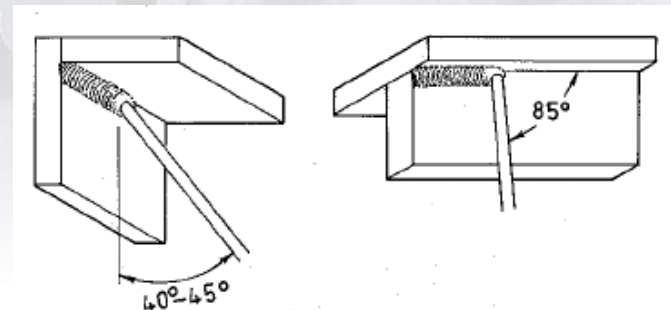
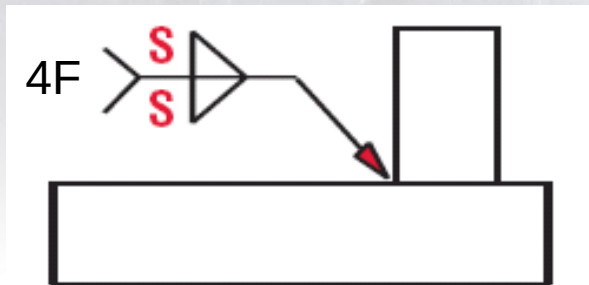
- Objective: To make a fillet weld on a tee joint in the vertical position welding down (AWS Position 3FD)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



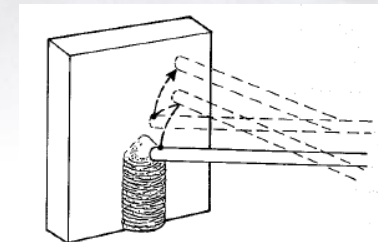
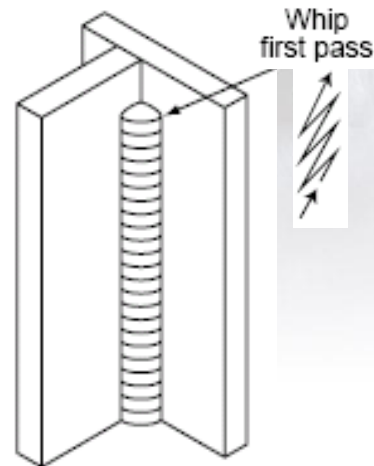
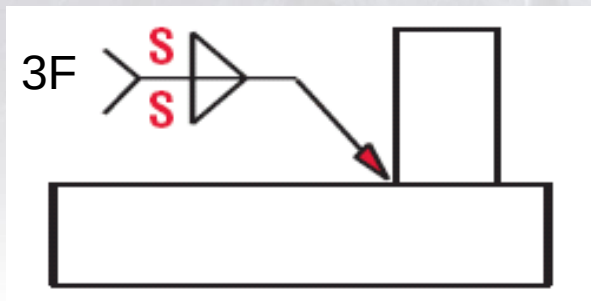
- Objective: To make a fillet weld on a lap joint in the overhead position (AWS Position 4F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



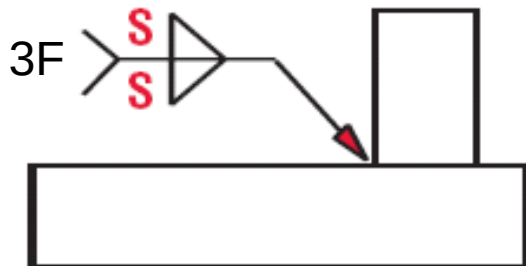
- Objective: To make a fillet weld on a tee joint in the overhead position (AWS Position 4F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate - 10 gauge*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



- Objective: To make a single pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate – 1/4"*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Electweld 180 (E6011) for AC*



- Objective: To make a three pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate – 1/4"*
 - *1/8" Fleetweld 5P+ (E6010) for DC or Fleetweld 180 (E6011) for AC*



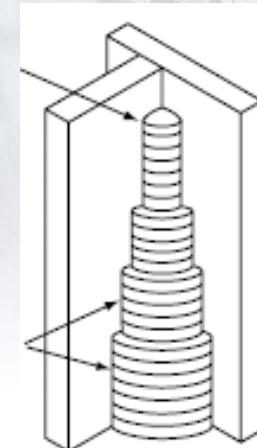
Whip
first pass



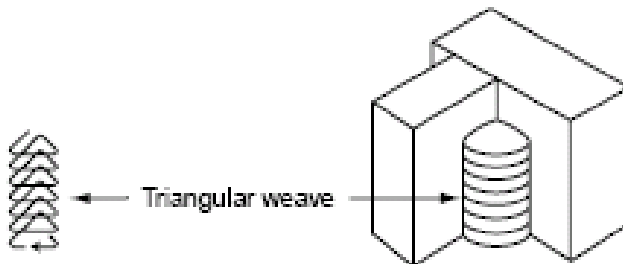
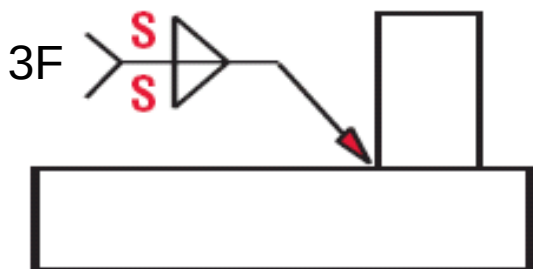
Box weave
second pass



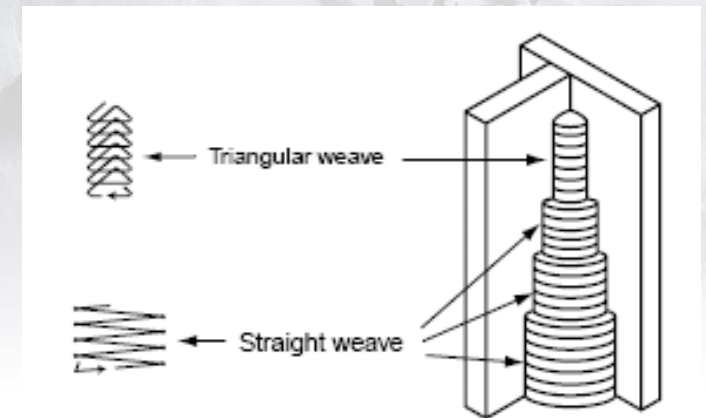
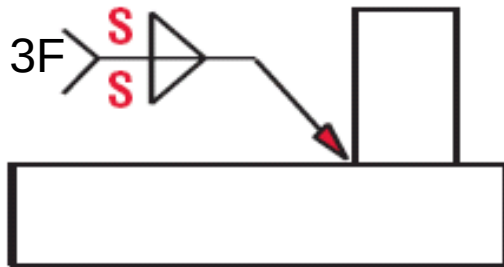
Straight weave



- Objective: To make a single pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate – 1/4"*
 - *1/8" Excalibur 7018 (E7018) for DC or Lincoln 7018AC (E7018) for AC*



- Objective: To make a three pass fillet weld on a tee joint in the vertical position welding up (AWS Position 3F)
- Equipment:
 - *Single Process - Constant Current Power Source*
 - Idealarc 250 and accessories
 - Precision TIG 225 and accessories
 - *Multi-Process*
 - Power MIG 350 MP
- Material:
 - *Mild Steel Plate – 1/4"*
 - *1/8" Excalibur 7018 (E7018) for DC or Lincoln 7018AC (E7018) for AC*





AWS Connection



- The *SMAW Welding Unit* of study incorporates the following information taken from the AWS EG 2.0 requirements:
 - *Set up for SMAW operations on carbon steel*
 - *Operate SMAW equipment on carbon steel*
 - *Make SMAW fillet welds on carbon steel*



English, Math, and Science Connection



- The unit, just completed, has covered parts of academic content listed in the National Academic Standards as follows:
 - **NM-PROB.CONN.PK-12.3:** *Recognizes and applies mathematics in contexts outside of mathematics.*
 - **NLA-STANDARD 1:** *Uses the general skills and strategies of the writing process.*
 - **NLA-STANDARD 7:** *Uses reading skills and strategies to understand and interpret a variety of informational texts.*
 - **NS-PHYSICAL SCIENCE:** *(Experiences) interactions of energy and matter.*