OPENING NOTES FOR THE TEACHER:

The Facilitator’s Manual is to be used as a reference tool for teachers to plan lessons related to the GMAW Units of Study.

The following lesson plans are based around the lesson slides in the GMAW PowerPoint presentations and should be used in conjunction with the units of study.

Print-outs can be made of each lesson if teachers want to hand hard copies to the students in the class.

Arc Welding Safety
Safe welding practices shall always be used.

- Teachers and students should read and understand the following before welding:
  - Warning Labels on welding equipment, with consumable packaging and in instruction manuals
  - Material Safety Data Sheets (MSDS) available with consumable packaging and online at http://www.lincolnelectric.com/en-us/support/msds/Pages/sds-search.aspx

- Teachers and students should also be familiar with the following information
**Electric Shock**

Contact with metal parts which are “electrically hot” can cause injury or death because of the effect of the shock upon your body or a fall which may result from your reaction to the shock. The electric shock hazard associated with arc welding may be divided into two categories which are quite different:

- Primary Voltage Shock (i.e. 230, 460 volts); and
- Secondary Voltage Shock (i.e. 20-100 volts).

The **primary voltage shock** is very hazardous because it is much greater voltage than the welder secondary voltage. You can receive a shock from the primary (input) voltage if you touch a lead inside the welder with the **power to the welder** “on” while you have your body, or hand, on the welder case or other grounded metal. Remember that turning the welder power switch “off” does not turn the power off **inside the welder**. Your welder should be installed by a qualified electrician so it will be correctly wired for the primary voltage which supplies it power and so the case will be connected to an earth ground. The case must be grounded so that if a problem develops inside the welder a fuse will blow, disconnecting the power and letting you know that repair is required. Never ignore a blown fuse because it is a warning that something is wrong.

A **secondary voltage shock** occurs when you touch a part of the **electrode circuit** — perhaps a bare spot on the electrode cable — at the same time another part of your body is touching the metal upon which you’re welding (work). To receive a shock your body must touch both sides of the welding circuit — electrode and work (or welding ground) — at the same time. To prevent secondary voltage shock, you must develop and use safe work habits. Remember the voltage at the electrode is highest when you are **not** welding (open circuit voltage).

- Wear **dry** gloves in good condition when welding.
- Do not touch the electrode or metal parts of the electrode holder with skin or wet clothing.
- Keep **dry** insulation between your body (including arms and legs) and the metal being welded or ground (i.e. metal floor, wet ground).
- Keep your welding cable and electrode holder in good condition. Repair or replace any damaged insulation.

Keep your gloves **dry** even if you have to keep an extra pair. Use plywood, rubber mats, or some other **dry** insulation to stand or lie upon. Insulate your body from the metal you are welding. Don’t rest your body, arms, or legs on the workpiece, especially if your clothing is wet or bare skin is exposed (and it should not be if you are dressed properly). In addition to the normal safety precautions, if welding must be performed under electrically hazardous conditions (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, if there is a high risk of unavoidable or accidental contact with the work piece or ground) use the following equipment:

- Semiautomatic DC Constant Voltage Welder
- DC Manual (Stick) Welder
- AC Welder with Reduced Voltage Control

Always inspect your electrode holder before turning the welder on. Replace the holder if it is damaged. Remember, a stick electrode is always “electrically hot” when the welder is on — treat it with respect. If you do experience a shock, think of it as a warning — check your equipment, work habits and work area to see what is wrong before continuing to weld.
FUMES AND GASES

The fume plume contains solid particles from the consumables, base metal, and base metal coating. For common mild steel arc welding, depending on the amount and length of exposure to these fumes, most immediate or short term effects are temporary, and include symptoms of burning eyes and skin, dizziness, nausea, and fever. For example, zinc fumes can cause metal fume fever, a temporary illness that is similar to the flu.

Long-term exposure to welding fumes can lead to siderosis (iron deposits in the lungs) and may affect pulmonary function. Bronchitis and some lung fibrosis have been reported.

Some consumables contain certain compounds in amounts which may require special ventilation and/or exhaust. These Special Ventilation products can be identified by reading the labels on the package. If Special Ventilation products are used indoors, use local exhaust. If Special Ventilation products are used outdoors, a respirator may be required. Various compounds are sometimes found in welding fume, for example:

**Chromium:** Chromium is on the IARC (International Agency for Research on Cancer) and NTP (National Toxicology Program) lists chromium as posing a carcinogenic risk to humans. Fumes from the use of stainless steel, hardfacing and other types of consumables contain chromium and/or nickel. Some forms of these metals are known or suspected to cause lung cancer in processes other than welding, asthma has also been reported. Therefore, it is recommended that precautions be taken to keep exposures as low as possible. OSHA recently adopted a lower PEL (Permissible Exposure Limit) for chromium.

**Manganese:** Manganese overexposure may affect the central nervous system, resulting in poor coordination, difficulty in speaking, and tremor of arms or legs. This condition is considered irreversible.

There is one easy way to reduce the risk of exposure to hazardous fumes and gases: keep your head out of the fume plume! As obvious as this sounds, the failure to follow this advice is a common cause of fume and gas overexposure because the concentration of fume and gases is greatest in the plume. Keep fumes and gases from your breathing zone and general area using natural ventilation, mechanical ventilation, fixed or moveable exhaust hoods or local exhaust at the arc. Finally, it may be necessary to wear an approved respirator if adequate ventilation cannot be provided.

There are also steps that you can take to identify hazardous substances in your welding environment. First, read the product label and material safety data sheet for the electrode posted in the work place or in the electrode or flux container to see what fumes can be reasonably expected from use of the product and to determine if special ventilation is needed. Secondly, know what the base metal is, and determine if there is any paint, plating, or coating that could expose you to toxic fumes and/or gases. Remove it from the metal being welded, if possible. If you start to feel uncomfortable, dizzy or nauseous, there is a possibility that you are being overexposed to fumes and gases, or suffering from oxygen deficiency. Stop welding and get some fresh air immediately. Notify your supervisor and co-workers so the situation can be corrected and other workers can avoid the hazard. Be sure you are following these safe practices, the consumable labeling and MSDS and improve the ventilation in your area. Do not continue welding until the situation has been corrected.

You should understand a few basic terms that will be used in this section:
Natural Ventilation is the movement of air through the workplace caused by natural forces. Outside, this is usually the wind. Inside, this may be the flow of air through open windows and doors.

Mechanical Ventilation is the movement of air through the workplace caused by an electrical device such as a portable fan or permanently mounted fan in the ceiling or wall.

Source Extraction (Local Exhaust) is a mechanical device used to capture welding fume at or near the arc and filter contaminants out of the air.

The ventilation or exhaust needed for your application depends upon many factors such as:

- workspace volume
- workspace configuration
- number of welders
- welding process and current
- consumables used (mild steel, hardfacing, stainless, etc.)
- allowable levels (TLV, PEL, etc.)
- material welded (including paint or plating)
- natural airflow

Your work area has adequate ventilation when there is enough ventilation and/or exhaust to control worker exposure to hazardous materials in the welding fumes and gases so the applicable limits for those materials is not exceeded. See Supplement 1 for the legal limits, the OSHA PEL (Permissible Exposure Limit), and the recommended guideline, the ACGIH TLV (Threshold Limit Value), for many compounds found in welding fume.

Important Safety Note:
When welding with electrodes which require special ventilation such as stainless or hardfacing (see instructions on container or MSDS) or on lead or cadmium plated steel and other metals or coatings which produce hazardous fumes, keep exposure as low as possible and below exposure limit values (PEL and TLV) for materials in the fume using local exhaust or mechanical ventilation. In confined spaces or in some circumstances, for example outdoors, a respirator may be required if exposure cannot be controlled to the PEL or TLV. Additional precautions are also required when welding on galvanized steel.

Source Extraction Equipment
Mechanical ventilation is an effective method of fume control for many welding processes. Because it captures fume near the arc or source of the fume, which is more efficient in most cases, local exhaust, also called "source extraction", is a very effective means to control welding fume.

Source extraction of welding fumes can be provided by mobile or stationary, single or multi-station, exhaust and/or filtration equipment designed with adjustable fume extraction arms nozzles or guns, by fixed enclosures, booths or tables with extraction canopies also known as down-draft, or by back-draft or cross-draft tables/booths. Source extraction of weld fume falls into two categories: low vacuum/high volume, or high vacuum/low volume.

Fume extraction is only one component in reducing welding fume. Users should also consider the selection of the welding process, welding procedure, or consumable. Many times a combination of fume extraction, training, process change, and/or consumable change is needed to reduce the amount of fume to acceptable levels. Solutions to a particular application may involve one or all of these factors and the user must determine which solution best fits their application.
OSHA regulations include specific requirements for exhaust systems which should be reviewed when selecting fume extraction systems.

**Working in Confined Spaces**

When arc welding in a confined area, such as a boiler, tank, or the hold of a ship, bear in mind that all the hazards associated with normal arc welding are amplified, so the precautions mentioned here are even more important. This subject is very complicated and only these precautions related to arc welding will be discussed in this brochure. Per OSHA document 29 CFR 1910.146, a particular area is considered a confined space if it:

1) Is large enough and so configured that an employee can bodily enter and perform assigned work; and
2) Has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry); and
3) Is not designed for continuous employee occupancy.

There is a greater danger that enough flammable gases may be present in the confined space to cause an explosion. The metal of the enclosure can become part of the welding circuit, so any metal you touch (the walls, floor, ceiling) is electrically "hot". Welding fumes can accumulate more rapidly, with a higher concentration; gases can force out the breathable air, suffocating you in the process.

Per OSHA document 29 CFR 1910.146(d)(5)(iii); after an area has been deemed a confined space, the existence of the following atmospheric hazards are to be determined:

1) Test for oxygen
2) Test for combustible gases and vapors
3) Test for toxic gases and vapors

The workplace and OSHA rules regarding confined spaces must be followed. Make sure that your body is insulated from the work-piece using dry insulation. Wear dry gloves and only use a well-insulated electrode holder. Semiautomatic constant voltage welders with cold electrode or stick welders equipped with a device to lower the no-load voltage are recommended, especially when the work area is wet. Make sure that there is adequate ventilation and exhaust (a respirator or an air-supplied respirator may be necessary depending on the application), and that there are no flammable coatings, liquids or gases nearby.

Lastly, you must have someone outside the enclosure trained to handle emergencies, with rescue procedures and a means to disconnect power to your equipment and pull you out if danger arises.

For more information on environmental products and solutions:

1. Lincoln Environmental Systems (E13.40)
2. Environmental System Selection Guide (MC05-183)
3. www.lincolnelectric.com Quick Link: "Safety"
### Supplement 1

**LISTED BELOW ARE SOME TYPICAL INGREDIENTS IN WELDING ELECTRODES AND THEIR TLV (ACGIH) GUIDELINES AND PEL (OSHA) EXPOSURE LIMITS**

<table>
<thead>
<tr>
<th>INGREDIENTS</th>
<th>CAS No.</th>
<th>TLV mg/m³</th>
<th>PEL mg/m³</th>
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<td>Aluminum and/or aluminum alloys (as Al)****</td>
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<td>15</td>
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<td>Aluminum oxide and/or Bauxite****</td>
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<tr>
<td>Zirconium alloys and compounds (as Zr)</td>
<td>12004-83-0</td>
<td>5</td>
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</tr>
</tbody>
</table>

**Supplemental Information:**

1. Not listed. Reference value maximum is 10 milligrams per cubic meter. PEL value for iron oxide is 10 milligrams per cubic meter. TLV value for iron oxide is 5 milligrams per cubic meter.
2. As respirable dust.
4. The PEL for chromium (VI) is 0.05 milligrams per cubic meter as an 8-hour time weighted average. The TLV for wood-fume chromium (III) is 0.05 milligrams per cubic meter. The TLV for insoluble chromium (VI) is 0.01 milligrams per cubic meter.
5. Values are for manganese(IV). STEL (Short Term Exposure Limit) is 3.0 milligrams per cubic meter. TLVs are those proposed by OSHA in 1990. PEL is 0.5 milligrams per cubic meter (ceiling value).
6. Values are for insoluble barium compounds. The TLV for soluble barium compounds is 0.5 mg/m³.

TLV and PEL values are as of April 2008. Always check Material Safety Data Sheet (MSDS) with product or on the Lincoln Electric website at http://www.lincolnelectric.com.
Supplement 2

BIBLIOGRAPHY AND SUGGESTED READING

ANSI Z87.1, Practice for Occupational and Educational Eye and Face Protection, American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

Arc Welding and Your Health: A Handbook of Health Information for Welding. Published by The American Industrial Hygiene Association, 2700 Prosperity Avenue, Suite 250, Fairfax, VA 22031-4319.

NFPA Standard 51B, Cutting and Welding Processes, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9146, Quincy, MA 02269-9959.


The following publications are published by The American Welding Society, P.O. Box 351040, Miami, Florida 33135. AWS publications may be purchased from the American Welding Society at http://www.aws.org or by contacting the AWS at 800-854-7149.


AWS F1.1, Method for Sampling Airborne Particulates Generated by Welding and Allied Processes.


AWS F1.3, Evaluating Contaminants in the Welding Environment: A Strategic Sampling Guide.

AWS F1.5, Methods for Sampling and Analyzing Gases from Welding and Allied Processes.

AWS F3.2, Ventilation Guide for Welding Fume Control

AWS F4.1, Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping That Have Held Hazardous Substances.

UNIT: GMAW

PROBLEM AREA

How do I run a straight bead using short arc transfer to fill the crater?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROB.CONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions
- NLA-STANDARD 3: Uses grammatical and mechanical conventions in written compositions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL ...

- Run a straight bead using short circuit transfer

TIME: INSTRUCTION TIME FOR THIS LESSON: 2 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- **Tools and Equipment:**
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package

- **Supplies:**
  - Mild Steel Plate – 3/16”
  - .035” SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

KEY TERMS:

**THE FOLLOWING TERMS ARE PRESENTED IN THIS LESSON AND APPEAR IN BOLD:**

- Bead
- Short arc transfer
- Contact Tip to Work Distance (CTWD)
- Crater
- Super Arc L-56
- Push Technique

**TEACHER NOTES:** Suggested discussions include information regarding the following:

**SHORT ARC TRANSFER**

- Much of the welding with the gas metal-arc process using CO2 as the shielding gas is done using the short arc transfer. In the short arc transfer, the tip of the electrode wire actually touches the work piece, shorting out the welding circuit. Immediately prior to the moment of contact, the tip of the wire may be molten or near molten. When contact occurs, under the heating effect of the short circuit, the globule at the end of the wire becomes completely fluid and, by surface tension, is drawn to the weld puddle and away from the electrode. A gap occurs and an arc is the re-established. A new cycle of globule-formation at the tip begins while the electrode wire, pushed by the wire feeder, moves toward contact with the work.

- The inductance determines the rate at which the current rises after the short in the cycle. It also has a direct effect on how many short circuits can be made per second with a given type and size of electrode and type of shielding gas. Shorting takes place 20 - 200 times per second. More inductance results in less shorts and more heat input. Less inductance results in more shorts and less heat input.

- Low voltage and low amperages characterize short arc transfer welding. The welding voltage is typically 16-22 volts; the amperage, 30-200 amperes, and the flow of CO2 shielding gas, 25-30 cubic feet per hour. Every electrode type and diameter has an optimum range of welding conditions. In mild steel welding, typically smaller wire diameters are used (.025” - .045”). Common gas mixtures include 100% CO2 or CO2 mixtures such as 75% Argon/ 25% CO2.

- The basis of GMAW is the continuously fed wire electrode. The arc is maintained when the welding current is shorted across the gap between the electrode and the work piece. The object is to establish
a good weld easily and quickly with the right procedure for any given job. It is this bead or series of beads, composed of a fused mixture of base metal and coiled filler metal that forms the weld.

- Spend sufficient time on these jobs to become proficient in:
  - Holding the proper distance away from the base metal and constant travel angle.
  - Moving the gun along the plate, to make a smooth uniform bead.
- During welding, observe the appearance of the molten puddle and learn to recognize a good weld bead as you're making it.
- Keep your eyes on the sides of the crater as the wire is fed mechanically through the gun assemble to the weld puddle so that you can quickly vary the speed of travel or gun angle to correct a poor bead.
- Correct contact tip to work distance (CTWD) will be developed by proper judgment of the weld deposit:
  - If the CTWD is too long, there will be a noticeable increase in spatter, weld porosity and the gun assembly will push the operator's hand away from the work piece. Penetration will be poor, overlap will be noticeable, sounds of the arc will pop and sputter (rather than a steady crackle) or the arc will shut on and off with poor bead appearance as the end result.
  - If the CTWD is too short, the gun will block visibility.
- When the rate of travel is too fast, the bead will be thin and stringy with poor penetration, but if the rate of travel is slow the weld metal will pile up and roll over with excess overlap.
- When the voltage is set too high the bead will be flat with excessive amounts of spatter. The wire may burn back into the contact tip.
- If the amperage setting is too low, burn back of the wire will occur stopping the wire from feeding out of the tip and bird-nesting back at the drive rolls will result.
- Extra activity: Use the 'click method' to determine the wire feed speed. Hold the gun trigger for 6 seconds allowing wire to feed out. Measure the wire fed over that period of time with a ruler. Multiply the inches by 10 for wire feed speed per minute.

**Advantages of Short Arc Transfer**

- All-position capability, including flat, horizontal, vertical-up, vertical-down and overhead.
- Handles poor fit-up extremely well and is capable of root pass work on pipe applications.
- Lower heat input reduces weldment distortion.
- Higher operator appeal and ease of use.
- Higher electrode efficiencies than SMAW, 93% vs. 64%

**Limitations of Short Arc Transfer**

- Restricted to sheet metal thickness range of .035”-1/8” and open roots of 3/16” or less.
- Poor welding procedure control can result in incomplete fusion called cold lapping.
Poor procedure control can result in excessive spatter and will increase weldment cleanup cost.

When welding outdoors, a wind block may be needed to prevent the loss of shielding gas.

**Super Arc L-56**
Premium copper coated MIG wire, **Super Arc L-56** is an excellent choice for welding on metals with a medium to high presence of millscale. For best performance use on clean, oil-free, and rust-free base material. Best weld appearance and toe wetting when compared to ER70S-3 and ER70S-4 classifications. **Super Arc L-56** has high silicon and manganese deoxidizer levels. Superior feedability and excellent arc characteristics are trademarks of **Super Arc L-56**. Shielding gases include argon/carbon dioxide blends, argon/oxygen blends, straight carbon dioxide, and three or four-part gas blends.

**INTEREST APPROACH:**
- Begin the lesson by demonstrating the GMAW process by using water, wax paper, and an eyedropper. Place the wax paper on a demonstration table. Slowly release the water from the eyedropper while pushing the eyedropper from right to left using proper GMAW welding technique. Make sure not break the surface tension of the water. Use the demonstration to begin your lesson on the GMAW process.

**TO GAIN PRACTICAL KNOWLEDGE OF CLASSROOM CONTENT, ALLOW 1 HR. FOR THE STUDENTS TO DO PRACTICE USING THE FOLLOWING EXERCISES:**

**Lesson Instructions**

**Exercise A:** Run stringer beads using short arc transfer
1. Clean the base metal and position flat on table.
2. Check the ground connection to table or work.
3. Adjust the voltage and amperage with the controls on the power source or wire feeder (wire feed speed), read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
4. Position the gun with the wire lightly touching the work; visible contact tip to work distance (CTWD) should be 3/8" to 1/2" away from the work piece, too close a CTWD will block visibility, yet too long will cause porosity in the weld due to loss of shielding.
5. Press the gun trigger to start the weld and release the trigger and pull the gun away to stop. Some welders accustomed to manual welding with stick electrodes tend to push the wire into the puddle as it burns away; since the wire is mechanically fed this must be avoided.
6. Hold the electrode perpendicular to the base metal inclined at 20 to 25˚. (push technique) Maintain a normal arc length, 3/8" to 1/2", and move the gun across the plate at a uniform rate. A right-handed welder normally works from right to left and left-handers in the opposite direction.
7. Make stringer beads approximately 1/4" wide for the full length of the plate. Skip 1/4" between beads and continue on both sides of the work piece.

**Sample on slide: 18 volts, 200 ipm, DC++**

**Exercise B:** To build a pad.
1. Follow same steps as above.
2. Run parallel beds about 6" in length.
3. Run beads toward you, away from you, and from the right and the left.
4. Overlap each new bead on last bead at least 1/4” of an inch.

SUMMARY OF CONTENT TEACHING STRATEGIES

ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:

• What happens if you have too long of a CTWD with the GMAW process?
• What will a too-high voltage setting do to the weld?
• What will a low Wire Feed Speed setting do to the weld?
• What do you do if a “bird-nest” occurs?
• What is the relationship between wire feed speed and amperage?
• What are the advantages and disadvantages of the push versus the drag technique?

APPLICATION:

• Extended Classroom Activity:
  − Have the students compare and contrast SMAW to GMAW by creating a short power point presentation. Items to address should include equipment, set-up, process, advantages, and disadvantages of each.

• SAE Activity:
  − Have the students determine where in their SAE they could use GMAW instead of SMAW. In what situations would one method be preferred over the other?

EVALUATION:

STUDENTS WILL BE EVALUATED ON THE SUCCESSFUL COMPLETION OF THE TWO EXERCISES.
UNIT: GMAW

PROBLEM AREA

- How do I make a fillet weld on a lap joint using short arc transfer in the horizontal position (AWS Position 2F)?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROB.CONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions
- NLA-STANDARD 3: Uses grammatical and mechanical conventions in written compositions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a fillet weld on a lap joint in the horizontal position (AWS position 2F)

TIME: INSTRUCTION TIME FOR THIS LESSON: 2 HR.

RESOURCES:

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- Supplies:
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  - .035" SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/25% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERMS ARE PRESENTED IN THIS LESSON AND APPEAR IN BOLD ITALICS:

- Lap joint
- Fillet weld
- Horizontal fillet weld (AWS position 2F)

TEACHER NOTES: Suggested discussions include information regarding the following:

A lap joint is welded with the bead made on the surface of one plate and the edge of the other producing a fillet weld. Fit work so there is no appreciable gap. Speed of welding, amperage, and quality of weld vary directly with fit up. On practical applications, most fillet welds on lap joints will be made in the horizontal position, with both base metal pieces horizontal. The ideal fillet weld has equal legs and a flat or slightly convex bead. Excess convexity wastes weld metal. A concave bead is susceptible to weld cracking.

INTEREST APPROACH:

- Show the students what a convex and concave bead looks like. Ask questions to the students that will lead them in a discussion on the advantages and disadvantages of each, why you should use a slightly convex bead, and how to properly make a slightly convex bead.

To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:
LESSON INSTRUCTIONS:

**Exercise**: Make a fillet weld on a lap joint in the horizontal position
1. Clean the base metal and position flat on table, overlapping approximately 2 inches.
2. Check the ground connection to table or work.
3. Adjust the voltage and amperage with the controls on the power source or wire feeder (wire feed speed), read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
4. Tack the lap joint at both ends.
5. Position the gun with the wire lightly touching the work at a 45 degree angle from the base material, directed to the root of the joint, inclined at 20 to 25˚. (Push technique). Maintain a normal CTWD, 3/8” to 1/2”, and move the gun across the plate at a uniform rate.
6. Press the gun trigger to start the weld and release the trigger to stop.
7. Visually inspect the bead. It should be uniform without overlap or undercuts, penetrating evenly into each plate.

**Sample on slide: .035” L-56, 18V, 200ipm, 75 Argon/ 25 CO2, DC+**

SUMMARY OF CONTENT TEACHING STRATEGIES

*ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:*

APPLICATION:

Extended Classroom Activity:
- Have the students create “Ask the Expert” cards. Each student will write two or three questions or concerns on the front of an index card that they encountered while performing the lesson (one card per question). When the students become proficient at this lesson, have them record their answers on the back of the index card. If the class is stumped, submit the question online to “Ask the Experts” on www.lincolnelectric.com. Keep the cards as a reference for the following year.

SAE Activity:
- Have the students run a cost analysis on SMAW and GMAW equipment and consumables. The cost analysis will help students determine what the ideal equipment for their SAE should be. Student should also look at both short and long terms cost such as repair and maintenance, expected life of the equipment and resale value.

EVALUATION:

*STUDENTS WILL BE EVALUATED ON THE SUCCESSFUL COMPLETION OF THE TWO EXERCISES.*
UNIT: GMAW

PROBLEM AREA

How do I make a fillet weld on a tee joint using short arc transfer in the horizontal position (AWS Position 2F)?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROBCONN.PK.12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions
- NLA-STANDARD 3: Uses grammatical and mechanical conventions in written compositions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a fillet weld on a tee joint using short arc transfer in the horizontal position (AWS Position 2F)

TIME: INSTRUCTION TIME FOR THIS LESSON: 2 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process -
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package

- Supplies:
  - Mild Steel Plate – 10 gauge
  - .035” SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/25% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERMS ARE PRESENTED IN THIS LESSON AND APPEAR IN BOLD:

- Tee joint
- Visual inspection
- Cubic feet per hour (CFH)

TEACHER NOTES: Suggested discussions include information regarding the following:

Joining members or plates coming in at 90 degree angle (tee joint) to each other with a fillet weld is the most commonly used joint in the welding industry. Most fillet welds are made in the horizontal position with the gun at a 45 degree angle to both the horizontal and vertical plates (see diagram below). When placed in this position, the welding speed is increased, the molten metal has a less tendency to run, and better penetration is achieved. For high strength joints make sure both sides of the plate are welded completely. Fillet welds can be made on a number of joint configurations; however, the lap joint and the tee joint are two of the most common.

![Diagram of gas flow rate](image-url)

Visual inspection is the most common type of weld inspection used in the welding industry. Most common weld defects can be detected by visual inspection including surface porosity, some cracking, improper bead shape, undercut, improper weld size, unequal leg length, irregular bead size and improper starts and stops.

Gas flow rate is measured in cubic feet per hour or CFH. It is normally adjusted with a gauge on the gas cylinder. If the flow rate is too low, the molten puddle will not be shielded from the atmosphere and the weld will have porosity. If the flow rate is excessively high, air from the atmosphere can be sucked into the molten weld puddle also causing porosity. High flow rates also wastes money because the excess gas adds no additional value.
INTEREST APPROACH:

- Begin this lesson by taking students into the shop area. Demonstrate the proper procedures for making a fillet weld using short arc transfer in the horizontal position with little or no explanation. Have each student observe and create a checklist of the procedures. Place students into groups to discuss the checklist and make any necessary corrections. Have student perform the procedures.

To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:

**Lesson Instructions**

**Exercise:** Make a fillet weld on a tee joint in the horizontal position

1. Clean base metal and tack plates together at 90˚ angle to each other.
2. Adjust voltage and amperage with the controls on the power source, or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cubic feet per hour.
3. Use push technique. Holding the gun assembly 45˚ from the horizontal plane, start the weld at the edge of the plate, and maintain 3/8” to ½” CTWD away from base metal for entire length of weld.
4. Observe the edges of puddle carefully as it forms under the arc. There may be some tendency to undercut the vertical plate. If travel speed and gun angle are correct, the bead will not undercut.
5. Maintain proper bead shape and size throughout the entire length of the weld. Bead size should be approximately 3/16” fillet for a single pass weld.
6. Visually Inspect

**Sample on slide:** .035” L-56, 18V, 200ipm, 75Ar/25CO2, DC++

**Summary of Content Teaching Strategies**

**Ask the following review questions regarding the lessons practiced and have the students log the information in a notebook for future reference:**

- What is the most commonly used joint in the welding industry?
- What is the proper gun angle for making a single pass GMAW fillet weld on a tee joint?

**Application:**

Extended Classroom Activity:

- Have the students create a “welding library” for the classroom. The library should include examples of different qualities of welds, research material about welding, and an “Ask the Expert” area. Additional materials can be added to the library by going to [www.jff.org](http://www.jff.org) and [www.lincolnelectric.com](http://www.lincolnelectric.com).

SAE Activity:

- Bring in a panel of local people involved in different aspects of the welding process to discuss their specific job roles and the level of training or education needed. Panel members should include a certified welder, a welding inspector, a project manager, and a welding engineer.

**Evaluation:**

Students Will Be Evaluated On The Successful Completion Of The Exercise.
• Objective: To make a fillet weld on a lap joint in the vertical position welding down (AWS position 3FD)
• Equipment:
  – Single Process - Constant Voltage Power Source & Wire Feeder
    ▪ Power MIG 215 or Power MIG 255C
  – Multi-Process –
    ▪ Composite: Power MIG 350 MP
    ▪ Combination: V-350/ LF-72 package
• Material:
  – Mild Steel Plate – 10 gauge
  – .035” SuperArc L-56 (ER70S-6)
  – 100% CO2 or 25% CO2/ 75% Argon blend shielding gas

UNIT: GMAW

PROBLEM AREA

• How do I make a fillet weld on a lap joint using the short arc process in the vertical position welding down (AWS Position 3FD)?

NATIONAL STANDARDS:

• NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
• NM-PROB.CONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
• NS-PHYSICAL SCIENCE: Structure and property of matter
• NS-PHYSICAL SCIENCE: Chemical Reactions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

• Make a fillet weld on a lap joint using the short arc process in the vertical position welding down (AWS Position 3FD)

TIME: INSTRUCTION TIME FOR THIS LESSON: 1.5 HR.

RESOURCES:

• AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
• GMAW Welding Guide (C 4.200)
• MIG Wire Product Catalog (C4.10)
WELDING

‘Learning to Weld’ Guide (LTW1)
New Lessons in Arc Welding

TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package
  - Supplies:
    - Mild Steel Plate – 10 gauge
    - .035” SuperArc L-56 (ER70S-6)
    - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD ITALICS:

- Vertical down fillet weld (AWS position 3FD)

TEACHER NOTES: Suggested discussions include information regarding the following:

VERTICAL-DOWN WELDING

Welds made in the **vertical position welding down** or **vertical-down** welds are applied at a fast pace. These welds are therefore shallow and narrow and are excellent for sheet metal. This technique should not be used on heavy material where large welds are required. Use the vertical up technique where large welds are required.

When welding **vertical down**, make stringer beads using the drag technique by tipping the gun in the direction of travel so the arc force helps hold the molten metal in the joint. Move as fast as possible, consistent with desired bead shape. Try to maintain the puddle so that the back of it looks like a horseshoe (Ω). If the back of the puddle becomes pointed (^), travel speed is too fast. If the back of the puddle is wider than it is long and oval (O), travel speed it too slow. Continue lowering the entire arm as the weld is made so the angle of the gun does not change.

The weld made in this exercise is done in the 3FD position or vertical position welded down. It is accepted that when the ‘D’ is not present in the AWS position (i.e. 3F), the direction of welding should be up.
INTEREST APPROACH:

- Demonstrate GMAW vertical down welding by using a GMAW welding gun on the chalk board without talking. When you are finished, gather students into small groups to discuss their observations. Next, perform the task again; however, this time have one of the students discuss the procedures while you demonstrate. Begin the lesson by making any necessary adjustments to the student’s verbal descriptions.

**TO GAIN PRACTICAL KNOWLEDGE OF CLASSROOM CONTENT, ALLOW 1 HR. FOR THE STUDENTS TO DO PRACTICE USING THE FOLLOWING EXERCISES:**

**LESSON INSTRUCTIONS**

**Exercise:** Make a fillet weld on a lap joint in the vertical position welding down
1. Clean base metal, tack plates together and secure in position.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
3. Holding the gun assembly 60˚ from the vertical plane, start the weld at the edge of the plate and maintain 3/8" to 1/2" CTWD away from base metal for entire length of weld.
4. Observe the edges of puddle carefully as it forms under the arc.
5. Maintain proper bead shape and size throughout the entire length of the weld.
6. Visually Inspect

**Sample on slide:.035” L-56, 18V, 200ipm, 75Ar /25CO2, DC+**

**SUMMARY OF CONTENT TEACHING STRATEGIES**

**ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:**

**APPLICATION:**

Extended Classroom Activity:
- Have the students create two lap joints, one with tight fit up and one with at least an 1/8" gap. Weld in the vertical down position observing for ease of operation, puddle control, travel speed and weld quality. Discuss how a little extra time spent in proper fit up can save time in welding.
SAE Activity:
- Have the students host a “business day,” in which area businesses are invited to learn how each student’s SAE could be of service to their business. Have each student create a display about their SAE and the skills they developed during class.

EVALUATION:
Students Will Be Evaluated On The Successful Completion Of The Two Exercises.
UNIT: GMAW

PROBLEM AREA

- How do I make a fillet weld on a tee joint using short arc transfer in the vertical position welding down (AWS Position 3FD)?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROBCONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions
- NLA-STANDARD 10: Understands the characteristics and components of the media.

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a fillet weld on a tee joint using short arc transfer in the vertical position welding down (AWS Position 3FD)

TIME: INSTRUCTION TIME FOR THIS LESSON: 1.5 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process -
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package

- Supplies:
  - Mild Steel Plate – 10 gauge
  - .035” SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

TEACHER NOTES: Suggested discussions include information regarding the following:

KEY TERMS:

THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD:

- Arc force

VERTICAL-DOWN WELDING

The weld made in this exercise is done in the 3FD position or vertical position welded down. It is accepted that when the ‘D’ is not present in the AWS position (i.e. 3F) the direction of welding should be up. Vertical-down welds are applied at a fast pace. These welds are, therefore, shallow and narrow and are excellent for sheet metal. Make stringer beads with the drag technique by tipping the gun in the direction of travel so the arc force helps hold the molten metal in the joint. Arc force is defined as “the axial force developed by a plasma arc.” This force is used during vertical down welding to help support the weld puddle.

When welding vertically down, move as fast as possible consistent with desired bead shape. Try to maintain the puddle so that the back of it looks like a horseshoe (Ω). If the back of the puddle becomes pointed (^), travel speed is too fast. If the back of the puddle is wider than it is long or oval (O), travel speed it too slow. The important thing is to continue lowering the entire arm as the weld is made so the angle of the gun does not change. Vertical-down welding gives thin, shallow welds. It should not be used on heavy material where large welds are required. Use the vertical up technique where large welds are required.
WELDING

INTEREST APPROACH:

- Hand each student a stack of index cards as they enter class. Each card should contain one step in the process of GMAW vertical down welding. Once class begins, have the students determine the correct sequence of steps. They can use any welding reference material as a guide.

To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:

LESSON INSTRUCTIONS

**Exercise:** Make a fillet weld on a tee joint in the vertical position welding down

1. Clean base metal, tack plates at a 90 degree angle and secure in position.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
3. Holding the gun assembly 60˚ from the vertical plane and 45 degrees from both vertical plates. Start the weld at the edge of the plate and maintain 3/8” to 1/2” CTWD away from base metal for entire length of weld.
4. Observe the edges of puddle carefully as it forms under the arc.
5. Maintain proper bead shape and size throughout the entire length of the weld.
6. Visually inspect

**Sample on slide: .035” L-56, 18V, 200ipm, 75Ar/25CO2, DC+**

SUMMARY OF CONTENT TEACHING STRATEGIES

ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:

APPLICATION:

Extended Classroom Activity:

- Host a competition during class. Each student will have five minutes to make a fillet weld using the short arc transfer in the vertical position welding down. Students can make as many as they choose in the allotted time; however, they can only submit one piece for the competition. As a group, have the students determine which is the best weld based on visual inspection.

SAE Activity:

- Have students create a promotional brochure about their SAE. Students having an entrepreneurial SAE can use the brochure to help generate business. Students that have a placement SAE can use the brochure as a supplement to their resume, focusing on their welding skills.

EVALUATION:

Students Will Be Evaluated On The Successful Completion Of The Exercise.
UNIT: GMAW

PROBLEM AREA

How do I make a square weld on a butt joint with a gap using short arc transfer in the vertical position welding down?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROB.CONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL ...

- Make a square weld on a butt joint with a gap using short arc transfer in the vertical position welding down.

TIME: INSTRUCTION TIME FOR THIS LESSON: 1.5 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- **Tools and Equipment:**
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process -
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package
- **Supplies:**
  - Mild Steel Plate – 10 gauge
  - .035” SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

KEY TERMS:

**THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD:**

- Butt joint
- Gap

TEACHER NOTES: Suggested discussions include information regarding the following:

Securely tack weld the plates at both ends, otherwise the heat input will cause the plates to move apart as depicted below.

![Diagram of butt joint with gap](image)

When welding a **butt joint** with a **gap**, use setting on the lower end of the setting range, keep the gun angle the same from the start to finish and stay on the leading edge of the puddle at all times. The gun angle should be approximately 60 degree from the vertical plate. Use a travel speed fast enough to stay on the leading edge of the puddle.

The weld made in this exercise is done in the vertical position welded down. It is accepted that when the ‘D’ is not present (i.e. 3F), the direction of welding should be up.

**INTEREST APPROACH:**

- Place two pieces of metal with a slight gap between them in front of the class. Ask the students if it is possible to weld two pieces of metal together with a gap between them. Record their responses. Ask the students during which situation would this be an appropriate technique to use.
To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:

**Lesson Instructions**

**Exercise:** Make a square weld on a butt joint with a gap

1. Clean base metal, tack plates at both ends with a slight gap between the parts.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
3. Start the weld at the top edge of the plate, bridge the gap and proceed in vertical down progression maintaining a 3/8” to ½” CTWD from base metal for entire length of weld. Point the wire electrode between the two plates, keeping the gun 60 degrees to the vertical plane. Watch the molten metal to be sure it distributes itself evenly on both edges and in between the plates.
4. Observe the edges of puddle carefully as it forms under the arc.
5. Maintain proper bead shape and size throughout the entire length of the weld
6. Visually Inspect

**Sample on slide: .035” L-56, 18V, 175ipm, 75Ar/ 25CO2, DC+**

**Summary of Content Teaching Strategies**

**Ask the following review questions regarding the lessons practiced and have the students log the information in a notebook for future reference:**

**Application:**

Extended Classroom Activity:
- Have students make different welding projects. (Project ideas available in Arc Welded Projects - Vol ii, iii and iv. See GMAW Resources for more information.) Projects could include a two wheel cart, a metal tool box, or a small engine stand. Submit your project and win cash prizes by entering free of charge in the James F. Lincoln Arc Welding Foundation Contest at [www.jlf.org](http://www.jlf.org). Raffle the projects off at the county fair as a fundraiser for the FFA chapter.

SAE Activity:
- Have the students forge a partnership with the maintenance department of the school corporation, the parks and recreation department, or with a city agency to increase a student’s skills and business opportunity.

**Evaluation:**

Students will be evaluated on the successful completion of the two exercises.
UNIT: GMAW

PROBLEM AREA

- How do I make a fillet weld on a tee joint using short arc transfer in the overhead position (AWS Position 4F)?

NATIONAL STANDARDS:

- NM-MEA.9-12.1: Understand measurable attributes of objects and the units, systems, and processes of measurement
- NM-PROB.CONN.PK-12.3: Recognize and apply mathematics in contexts outside of mathematics.
- NS-PHYSICAL SCIENCE: Structure and property of matter
- NS-PHYSICAL SCIENCE: Chemical Reactions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a fillet weld on a tee joint using short arc transfer in the overhead position (AWS Position 4F)

TIME: INSTRUCTION TIME FOR THIS LESSON: 1.5 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package
- Supplies:
  - Mild Steel Plate – 10 gauge
  - .035" SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD ITALICS:

- Overhead fillet weld (4F)

TEACHER NOTES: Suggested discussions include information regarding the following:

OVERHEAD WELDING

The difficulties with welding overhead are putting the molten metal where it is wanted and making it stay there. If too much molten metal is deposited, gravity will pull it downwards and cause it to “drip”. When welding overhead, run stringer beads. Don’t whip, break the arc, move out of the puddle, or move too fast in any direction. Use a wire feed speed (WFS) near mid range and keep the electrode nearly perpendicular to the joint.

INTEREST APPROACH:

- Have several different fillet welds made using the short arc transfer in the overhead position for students to evaluate. One weld should be a correct overhead weld, one should use a whipping motion, another should show where the welder moved out of the puddle and another where “dripping” occurred. Have the students determine what causes each problem, how to prevent it, and what the correct procedure should be.

To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:
LESSON INSTRUCTIONS

Exercise: Make a fillet weld on a tee joint in the **overhead** position
1. Clean base metal, tack plates, and secure in position.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
3. Start the weld at the edge of the plate, and maintain 3/8" to 1/2" CTWD away from base metal for entire length of weld. Use the push technique with a slight circular motion favoring the top plate. Keep the gun 60 degrees to the vertical plane. Watch the molten metal to be sure it distributes itself evenly between the plates.
4. Observe the edges of puddle carefully as it forms under the arc.
5. Maintain proper bead shape and size throughout the entire length of the weld.
6. Visually Inspect

**Sample on slide: .035” L-56, 18V, 200ipm, 75Ar/25CO2, DC+**

SUMMARY OF CONTENT TEACHING STRATEGIES

**ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:**

APPLICATION:

Extended Classroom Activity:
- Run the shop like a business where community members or businesses bring in items that need to be repaired or fabricated. Have the students run all aspects of the business such as charging fees for supplies, creating invoices and statements, handling customer’s needs, and ordering supplies.

SAE Activity:
- Have students take pictures of where they used GMAW overhead welding in their SAE. Have the students assemble the pictures in a collage with a 50 word description for each activity. Discuss each picture and the process with the students.

EVALUATION:

Students will be evaluated on the successful completion of the two exercises.
UNIT: GMAW

PROBLEM AREA
How do I make a three pass fillet weld on a tee joint in the horizontal position (AWS Position 2F) using short arc transfer?

NATIONAL STANDARDS:

- **NM-MEA.9-12.1**: Understand measurable attributes of objects and the units, systems, and processes of measurement
- **NM-PROB.CONN.PK-12.3**: Recognize and apply mathematics in contexts outside of mathematics.
- **NS-PHYSICAL SCIENCE**: Structure and property of matter
- **NS-PHYSICAL SCIENCE**: Chemical Reactions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a three pass fillet weld on a tee joint in the horizontal position (AWS Position 2F) using short arc transfer

TIME: INSTRUCTION TIME FOR THIS LESSON: 2 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
WELDING

connects your world

- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding

TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 215 or Power MIG 255C
  - Multi-Process
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package
- Supplies:
  - Mild Steel Plate – 1/4”
  - .035” SuperArc L-56 (ER70S-6)
  - 100% CO2 or 75% Ar/ 25% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD ITALICS:

- Three pass

TEACHER NOTES: Suggested discussions include information regarding the following:

Joining members or plates coming in at 90 degree angle (tee joint) to each other with a fillet weld is the most commonly used joint in the welding industry. Most fillet welds are made in the horizontal position. When placed in this position, the welding speed is increased, the molten metal has less tendency to run, and better penetration is achieved. For high strength joints make sure both sides of the plate are welded completely.

Three pass welds are used to make larger welds that cannot be made in a single pass. After the first pass is made in the horizontal position, a second pass is put in on the bottom toe of the first weld. The second pass should cover 75-90% of the first weld and creates a shelf for the third pass. The third pass is placed on the previous two beads covering the second pass 50%. This technique results in a three pass weld with a flat to slightly convex weld face.

INTEREST APPROACH:

- Begin the lesson by reviewing how to make a three pass fillet weld in the horizontal position using SMAW. Next, have the students infer how making a three pass fillet weld in the horizontal position using GMAW is different.

To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:
Lesson Instructions

**Exercise:** Make a three pass fillet weld on a tee joint in the horizontal position

1. Clean base metal and tack plates together at 90˚ angle to each other.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 18—22 volts, 100 - 250 ipm. The flow of gas should be 18—25 cu. feet per hour.
3. Use push technique. Holding the gun assembly 45˚ from the horizontal plane, start the weld at the edge of the plate, and maintain 3/8” to 1/2” CTWD away from base metal for entire length of weld.
4. Observe the edges of puddle carefully as it forms under the arc. There may be some tendency to undercut the vertical plate. If travel speed and gun angle are correct, the bead will not undercut.
5. Maintain proper bead shape and size throughout the entire length of the weld. Bead size should be approximately 3/16” fillet for one pass.
6. Place second pass on the lower toe of the first pass using a 60 degree gun angle from the horizontal plane and covering 75-90% of the first bead.
7. Place third pass on top toe of the first pass using a 25-30 degree gun angle. Allow the bead to wet down over the second pass by 50% to produce a flat face on the overall bead.
8. Visually Inspect

**Sample on slide: .035” L-56, 18V, 200ipm, 75Ar/ 25 CO2, DC+**

**SUMMARY OF CONTENT TEACHING STRATEGIES**

**ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:**

**APPLICATION:**

Extended Classroom Activity:
- Create a welding "Wall of Fame," where only the best welds for GMAW and SMAW are placed. Make sure that the "Wall of Fame" includes each joint type, welding position, and weld types.

SAE Activity:
- Have the students select a piece of equipment that is needed for their SAE (e.g. if a student has a beef production SAE the student may need a watering trough built.) Help the students create the bill of materials, check the student’s progress, and upon completion visually inspect all welds.

**EVALUATION:**

Students will be evaluated on the successful completion of the two exercises.
UNIT: GMAW

PROBLEM AREA

- How do I make a horizontal fillet weld on a tee joint using axial spray transfer (AWS Position 2F)?

NATIONAL STANDARDS:

- **NM-MEA.9-12.1:** Understand measurable attributes of objects and the units, systems, and processes of measurement
- **NM-PROB.CONN.PK-12.3:** Recognize and apply mathematics in contexts outside of mathematics.
- **NS-PHYSICAL SCIENCE:** Structure and property of matter
- **NS-PHYSICAL SCIENCE:** Chemical Reactions

STUDENT LEARNING OBJECTIVES: AS A RESULT OF THIS LESSON, THE STUDENT WILL …

- Make a horizontal fillet weld on a tee joint using axial spray transfer (AWS Position 2F)

TIME: INSTRUCTION TIME FOR THIS LESSON: 2 HR.

RESOURCES:

- AWS ‘Safety in Welding, Cutting, and Allied Processes’ (ANSI Z49.1)
- GMAW Welding Guide (C 4.200)
- MIG Wire Product Catalog (C4.10)
- ‘Learning to Weld’ Guide (LTW1)
- New Lessons in Arc Welding
TOOLS, EQUIPMENT, AND SUPPLIES:

- Tools and Equipment:
  - Single Process - Constant Voltage Power Source & Wire Feeder
    - Power MIG 255C
  - Multi-Process
    - Composite: Power MIG 350 MP
    - Combination: V-350/ LF-72 package

- Supplies:
  - Mild Steel Plate – ¼”
  - .045” SuperArc L-56 (ER70S-6)
  - 90% Ar/ 10% CO2 blend shielding gas

KEY TERMS:

THE FOLLOWING TERM IS PRESENTED IN THIS LESSON AND APPEARS IN BOLD:

- Axial spray transfer

TEACHER NOTES: Suggested discussions include information regarding the following:

Axial spray transfer or ‘spray transfer’ is aptly named; a mist of tiny drops of molten metal from the electrode wire literally sprays forcibly from the electrode tip, through the length of the arc, and into the weld joint. High currents and voltages are used, resulting in high deposition rates, which tend to limit spray transfer to heavy welds in the flat or horizontal position. The arc length is maintained constant as wire is fed from the tip of the gun, and the arc is smooth and stable. Penetration is deep and the puddle is very fluid and usually large in diameter. As shown below, the electrode tip is pointed and the weld metal, under the arc force, is emitted from the point.

For axial spray transfer to occur, at least 80% Argon must be present in the gas blend. This mode of transfer is most applicable to heavy single-pass or multiple pass weldments. Aluminum welding can be done using spray transfer in all welding positions by using very thin aluminum electrode wires, 1/16” or less in diameter.

Advantages of Axial Spray Transfer

- High deposition rates.
- High electrode efficiency of 98% or more.
- Employs a wide range of filler metal types in an equally wide range of electrode diameters.
- Excellent weld bead appearance.
- High operator appeal and ease of use.
- Requires little post weld cleanup.
- Absence of weld spatter.
WELDING

**Excellent weld fusion.**

**Lends itself to semiautomatic, robotic, and hard automation applications.**

**Limitations of Axial Spray Transfer**

- Restricted to the flat and horizontal welding positions.
- The higher-radiated heat and the generation of a very bright arc require extra welder and bystander protection.
- The use of axial spray transfer outdoors may require a wind block.
- The shielding used to support axial spray transfer (more than 80% Argon) costs more than 100% CO2.

**INTEREST APPROACH:**

- Have the students take two 1/4 inch plates 6 inches long and make a tee joint. Make a 1/4 inch fillet using the short arc transfer on one side and a 1/4 inch fillet using axial spray transfer on the other side. Time each weld. Have the students comment on the differences in speed and appearance of each mode of transfer.

**To gain practical knowledge of classroom content, allow 1 hr. for the students to do practice using the following exercises:**

**LESSON INSTRUCTIONS**

**Exercise:** Make a fillet weld on a tee joint using axial spray transfer.

1. Clean base metal and tack plates together at 90° angle to each other.
2. Adjust voltage and amperage with the controls on the power source or wire feeder (wire feed speed); read the voltage by using the meters and adjust to 23 – 30 volts and 375-500 ipm, the flow of gas (90%Ar/10%CO2) at 25 - 40 cu. feet per hour.
3. Use push technique. Holding the gun assembly 45° from the horizontal plane, start the weld at the edge of the plate and maintain 3/8” to 1/2” CTWD away from base metal for entire length of weld.
4. Observe the edges of puddle carefully as it forms under the arc. There may be some tendency to undercut the vertical plate. If travel speed and gun angle are correct, the bead will not undercut.
5. Maintain proper bead shape at beginning, middle, and same size at the end of plate.
6. Visually inspect

**Sample on slide:** .045” L-56,475 ipm, 28 volts, 90Ar/10CO2, DC+**
SUMMARY OF CONTENT TEACHING STRATEGIES

ASK THE FOLLOWING REVIEW QUESTIONS REGARDING THE LESSONS PRACTICED AND HAVE THE STUDENTS LOG THE INFORMATION IN A NOTEBOOK FOR FUTURE REFERENCE:

APPLICATION:

Extended Classroom Activity:
- Host an AgriScience Fair competition for your welding students. Example experiments could include:
  - How are the short arc transfer and the spray arc transfer different?
  - How do different cooling methods affect welds? (i.e. water, oil, air or thermal blanket)
  - How can distortion be predicted and controlled during the welding process? (i.e. weld sequence, using clamps, offset the base materials and joint configuration)

SAE Activity:
- Have students develop a future plan of action sheet. Questions should focus on how they plan to apply this course to their SAE. Students should assess several specific situations and how they plan to apply the skills they learned to that situation. Students should also record what they want to do to continue learning about welding and specific steps in expanding their SAE.

EVALUATION:

Students will be evaluated on the successful completion of the two exercises.
RESOURCES AVAILABLE FROM LINCOLN ELECTRIC:
(www.lincolnelectric.com)

Learning to Weld (LTW1)


ADDITIONAL INFORMATION REGARDING ALL REFERENCED EQUIPMENT CAN BE ACCESSED AT:


ENVIRONMENTAL:

RESOURCES AVAILABLE FROM THE JAMES F. LINCOLN FOUNDATION:
(www.jff.org)

The Procedure Handbook - #1 Choice of Welding Educators

New Lessons in Arc Welding
How to Read Shop Drawings
Metals and How to Weld them
Arc Welded Projects (Vol ii, iii, iv)
WELDING

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