Wire Feed Welding

WIRE FEED WELDING

LAKE WASHINGTON INSTITUTE OF TECHNOLOGY WELDING DEPARTMENT

OpenWA

Olympia, WA

CONTENTS

INTRODUCTION AND COURSE OUTCOMES

We are excited to introduce you to the art and science of wire feed welding, a versatile and essential technique in the realm of metal fabrication and joining! Whether you are a seasoned professional looking to refine your skills or a newcomer eager to dive into the world of welding, this guide is designed to be your comprehensive companion as you embark on your wire feed welding journey.

COURSE DESCRIPTION

This (lecture) course focuses on the principles, procedures, and operation of equipment to properly and safely use the Gas Metal Arc Welding (GMAW), Flux Core Arc Welding (FCAW), including both the dual shield and inner-shield processes.

This (lab) course focuses on the application and operation of equipment to use properly and safely the Gas Metal Arc Welding (GMAW) and Flux Cord Arc Welding (FCAW) equipment.

COURSE OUTCOMES

Upon successful completion of this (lecture) course students will be able to:

- Identify and safely assemble equipment needed for GMAW and FCAW
- Prepare a work area for GMAW and FCAW
- Prepare metal for GMAW and FCAW procedures using proper joint design, equipment, and different joint preparation techniques
- List the advantages and limitations, types of power sources, different types of welding guns and selecting different welding wire
- Identify and use common types of shop equipment and hand tools to safely perform GMAW and FCAW welding/fabrication procedures
- List common considerations for using wire welding carbon steel, aluminum, stainless steel, and copper
- Comply with hazardous material laws and processes
- Follow industry standard safe practices, including the using and wearing of all safety equipment needed to weld or be in a welding environment

Upon successful completion of this (lab) course students will be able to:

- Select the proper metals and consumable materials, including electrodes, wire, filler metal, and/or shielding gases, for various welding tasks by using metallurgy principles
- Prepare metal for welding or cutting procedures using proper equipment and joint preparation techniques for ferrous and non-ferrous metals

- Use welding machines, shop equipment, and hand tools to safely perform welding and/or fabrication procedures
- Select, assemble, and adjust welding machines for various processes to produce welds that meet AWS standards
- Demonstrate the ability to start an arc, run a bead, and assess a weld puddle
- Use proper welding techniques to produce welds on lap joints, corner joints, T-joints, and/or butt joints in a variety of positions, including 1F, 2F, 3F, and 4F and/or 1G, 2G, 3G, and 6G
- Use math to make equipment adjustments and/or calibrations and to complete fabrication projects
- Use visual inspection methods and/or destructive testing to identify defects and/or discontinuities
- Follow ANSI Z49 safety standards, including recommended practices for personal protective equipment and hazardous material laws/processes

LICENSES AND PERMISSIONS

FOR FURTHER INFORMATION

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ABOUT THIS BOOK

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PART I.

SAFETY

Welding is a crucial process used in various industries to join metals, fabricate structures, and create intricate components. While welding offers numerous benefits, it also comes with inherent risks that demand utmost attention to safety. Welding operations involve high temperatures, intense light, and the potential for exposure to hazardous fumes and materials.

Ensuring welding safety is paramount to safeguarding the well-being of both welders and those in the surrounding environment. By understanding the potential risks, adopting proper safety measures, and adhering to established protocols, welding professionals can create a secure work environment that allows for efficient and effective welding while minimizing the potential for accidents, injuries, and long-term health issues.

LEARNING OBJECTIVES

By the end of this module you should be able to demonstrate the following skills:

- Identify and use common types of shop equipment and hand tools to safely perform welding/fabrication procedures.
- Follow industry standard safe practices, including the using and wearing of all personal protective equipment (PPE) needed to weld or to be in a welding environment.
- Comply with hazardous material laws and processes.

CHAPTER 1.

NAVIGATING COMMON WELDING HAZARDS

Welding is a skill that holds immense potential for creating and shaping, yet it is not without its share of risks and hazards. To embark on a welding journey with confidence and competence, it is crucial to navigate and mitigate common welding hazards effectively. By understanding these hazards and implementing appropriate safety measures, welders can ensure their well-being while achieving exceptional results. This reading presents a comprehensive guide to navigating common welding hazards and prioritizing safety in the welding environment.

ARC FLASH AND ELECTRICAL SHOCK

Arc flash and electrical shock are inherent dangers in welding, particularly during processes like Shielded Metal Arc Welding (SMAW) and Gas Metal Arc Welding (GMAW). The intense light emitted during welding can cause arc flash, potentially leading to eye injuries. Furthermore, improper handling of electrical equipment can result in electrical shock. To navigate these hazards:

- Utilize proper welding helmets with auto-darkening filters to shield your eyes from arc flash.
- Wear dry and insulating gloves and protective clothing to minimize the risk of electrical shock.
- Inspect cables, connectors, and electrical equipment for damage before use, and avoid water or damp areas while welding.

FIRE AND EXPLOSIONS

Welding generates extreme heat, sparks, and molten metal, all of which pose a fire hazard. Additionally, when working with flammable materials or in confined spaces, the risk of explosions increases. To mitigate these hazards:

- Clear the work area of flammable materials, liquids, and gases before starting the welding process.
- Place fire-resistant blankets or screens around the welding area to prevent sparks from igniting nearby objects.
- Have a fire extinguisher readily available and ensure all workers know how to use it effectively.

TOXIC FUMES AND GASES

Welding produces fumes and gases that, if inhaled, can lead to respiratory issues and long-term health problems. Welders must be vigilant about controlling exposure to these hazardous substances. To address this concern:

- Work in well-ventilated areas, ideally with local exhaust ventilation to remove fumes and gases at the source.
- Wear proper respiratory protection, such as N95 respirators or powered air-purifying respirators, when working in confined spaces or areas with inadequate ventilation.

BURNS AND UV RADIATION

The intense heat generated during welding can lead to severe burns on the skin and eyes. UV radiation emitted during welding can cause arc eye, a painful condition similar to sunburn. To protect against burns and UV radiation:

- Wear flame-resistant clothing, including long sleeves, pants, and leather aprons, to shield the skin.
- Employ appropriate welding helmets with shaded lenses to prevent arc eye and protect your eyes from harmful UV rays.

NOISE AND HEARING DAMAGE

Welding processes produce noise levels that can lead to hearing damage over time. To safeguard your hearing:

- Wear hearing protection, such as earplugs or earmuffs, especially when engaged in prolonged welding tasks or working in noisy environments.

Navigating these common welding hazards necessitates not only awareness but also proactive measures. By following safety protocols, using appropriate personal protective equipment (PPE), and adhering to industry guidelines, welders can confidently tackle their projects while minimizing risks.

CHAPTER 2.

PERSONAL PROTECTIVE EQUIPMENT

Personal protective equipment (PPE) serves as the shield that safeguards welders from the diverse hazards present in their work environment. In the welding realm, where intense heat, sparks, and harmful substances are part of the daily routine, PPE takes on a pivotal role in ensuring not only the success of projects but, more importantly, the safety and well-being of the individuals behind the welder's mask. Read on to learn about the significance of PPE for welders and key components of PPE.

PROTECTION AGAINST THERMAL HAZARDS

Welding is synonymous with heat—both its creative power and its potential danger. Flame-resistant clothing is a staple of a welder's PPE ensemble. With long-sleeved jackets, pants, and aprons crafted from materials that resist ignition and melting, welders are equipped to guard against burns and molten metal splatter. Welding gloves, often reinforced with heat-resistant materials, provide a barrier between hands and hot surfaces. These PPE items offer more than physical protection; they bestow welders with the confidence to manipulate heat for their artistic pursuits while mitigating risk.

SAFEGUARDING THE EYES AND FACE

The welding arc emits intense light and harmful UV radiation that can wreak havoc on unprotected eyes and skin. The welding helmet, an iconic piece of PPE, is engineered with a filter that automatically darkens upon detecting the arc's brightness. This instant shade shields welders' eyes from harmful rays, preventing conditions like arc eye—a painful reminder of the importance of proper eye protection. Additionally, safety glasses with shaded lenses provide added defense during setup and non-welding tasks.

RESPIRATORY PROTECTION

The fumes and gases produced during welding contain toxic substances that pose a health risk if inhaled. Welders must equip themselves with appropriate respiratory protection. Disposable masks or reusable respirators equipped with filters tailored to welding fumes act as the first line of defense against harmful particulates. Adhering to these respiratory precautions ensures that welders breathe easy even in the midst of hazardous fumes.

HEARING PRESERVATION

Welding operations generate noise levels that, over time, can lead to hearing loss. Prolonged exposure to these high decibels necessitates hearing protection. Earplugs or earmuffs shield welders' ears from the cacophony, preserving their hearing for the years to come.

FOOTWEAR AND BODY PROTECTION

Boots with metatarsal guards offer protection against falling objects and heavy tools, while also providing insulation against electric shock. Furthermore, leather aprons safeguard the body from sparks, hot metal, and molten splatter.

CHAPTER 3.

CAREER SPOTLIGHT: OSHA WELDING INSPECTOR

An Occupational Safety and Health Administration (OSHA) welding inspector is a specialized professional responsible for ensuring that welding and related processes are conducted in compliance with OSHA regulations and industry standards. These inspectors play a critical role in safeguarding the health, safety, and well-being of workers involved in welding operations. Their expertise helps prevent accidents, injuries, and potential hazards associated with welding and allied activities. Read on to learn about key responsibilities of an OSHA welding inspector.

INSPECTION AND COMPLIANCE

Welding inspectors conduct thorough inspections of welding operations and related activities to ensure they comply with OSHA safety regulations and industry standards. They examine welding equipment, work practices, and procedures to identify potential hazards and areas of non-compliance.

Welding Procedure Review

Inspectors assess welding procedures and techniques to ensure they adhere to established standards. They review documents such as Welding Procedure Specifications (WPS) to verify that welding processes are conducted correctly and safely.

Weld Quality Evaluation

Inspectors assess the quality of welds by examining weld joints for defects, discontinuities, and imperfections. They verify that the welds meet the required standards and specifications for strength, integrity, and durability.

Equipment Inspection

Inspectors examine welding equipment, machinery, and tools to confirm that they are properly maintained, calibrated, and in good working condition. They ensure that safety features are functional and that equipment is used correctly.

DOCUMENTATION AND RECORD-KEEPING

Welding inspectors maintain accurate records of inspections, findings, and corrective actions. Proper documentation is essential for tracking compliance, identifying trends, and addressing potential issues promptly.

SAFETY RECOMMENDATIONS

Based on their findings, inspectors provide recommendations and guidance to employers and workers to improve safety practices, mitigate hazards, and enhance overall welding operations.

HAZARD IDENTIFICATION AND RISK ASSESSMENT

Inspectors identify potential welding-related hazards, such as exposure to fumes, gases, or radiation, and assess associated risks. They suggest measures to control or eliminate these hazards to protect workers' health.

TRAINING AND EDUCATION

Inspectors may participate in training and education programs, delivering workshops or presentations to educate welders, supervisors, and management about proper welding techniques, safety protocols, and OSHA regulations.

INCIDENT INVESTIGATION

In the event of welding-related accidents, injuries, or incidents, inspectors conduct thorough investigations to determine the causes, contributing factors, and lessons learned. They recommend strategies to prevent similar incidents in the future.

ENFORCEMENT AND COMPLIANCE ASSISTANCE

While their primary goal is to promote safety, inspectors also have the authority to issue citations, penalties, and fines for violations of OSHA standards. However, they often focus on compliance assistance and collaborate with employers to address issues before resorting to enforcement actions.

CHAPTER 4.

CAREER SPOTLIGHT: SAFETY FOR ALL

Welding safety is intrinsically linked to welding careers due to the critical importance of maintaining a secure work environment for both welders and those in the surrounding vicinity. The safety of personnel, the quality of the work produced, and the reputation of the welding professional are all influenced by adherence to proper safety practices. Read the information below to learn how how welding safety is connected to welding careers.

HUMAN WELL-BEING

The well-being of welding professionals is paramount. Unsafe welding practices can lead to injuries, burns, respiratory issues, and long-term health problems due to exposure to welding fumes, arc radiation, and other hazards. A welding career can only be sustainable and fulfilling when the safety of the worker is prioritized.

PRODUCT QUALITY

Welding safety contributes to producing high-quality welds. Accidents and injuries resulting from inadequate safety measures can lead to poor workmanship, affecting the quality and integrity of the welded components. Quality control and safety go hand in hand, as defects caused by unsafe practices can compromise the functionality of the finished product.

INDUSTRY REGULATIONS AND STANDARDS

Many industries have strict regulations and standards related to welding safety. Adhering to these regulations is crucial for welding careers, as non-compliance can result in legal consequences, fines, and reputational damage.

PROFESSIONAL REPUTATION

A welder's reputation is built on their ability to consistently produce safe and reliable welds. A history of accidents or safety violations can tarnish a welder's reputation and limit opportunities for career advancement.

EMPLOYER EXPECTATIONS

Employers expect their welding professionals to prioritize safety and follow established safety protocols. Welders who demonstrate a commitment to safety are valued by employers for their role in maintaining a safe work environment.

EFFICIENCY AND PRODUCTIVITY

A safe work environment enhances overall efficiency and productivity. When welders can work confidently and without the fear of accidents, they can focus on producing quality work in a timely manner.

LONGEVITY OF THE CAREER

Welding careers span several decades. Prioritizing safety from the outset can help prevent injuries and health issues that might otherwise lead to premature career exits.

CONTINUING EDUCATION

As welding technology evolves, so do safety practices. Staying up-to-date with the latest safety standards and procedures through continuing education and training is essential for career development and advancement.

PROMOTION AND ADVANCEMENT

Demonstrating a strong commitment to welding safety can open doors for career advancement. Employers are more likely to promote individuals who show dedication to safety and a strong understanding of safe work practices.

CHAPTER 5.

SAFETY AGREEMENT

Safety is paramount in welding. We will delve into the critical safety measures and precautions that must be taken to protect yourself and those around you during the welding process. From personal protective equipment (PPE) to ventilation and fire prevention, our welding safety agreement, safety plan, and everyone's corporation will help ensure safety at all times.

Students are not allowed to weld until they have signed and submitted the safety agreement to their instructor.

SAFETY AGREEMENT

Safety in the classroom and the welding shop is extremely important. The student must recognize and accept that safety is an individual responsibility and act accordingly.

1. Wearing ANSI 87 rated eye protection is mandatory at all times in the Welding Lab.
2. Student should wear a respirator with ANSI approved filter when welding, grinding, or cutting. Respirators must be worn when welding, cutting, or grinding stainless steels.
3. Cotton, leather, wool, or other natural fiber clothing must be worn. No synthetic clothing unless OSHA/ANSI approved.
4. Leather or synthetic leather work boots, above-the-ankle lace preferred, steel toes preferred. Pant legs must cover the top of the boot.
5. Hearing protection is required. Ear plugs are not provided. Low profile earmuffs are permissible as well.
6. The student must wear full face protection when grinding. (This means a ANSI approved full face shield, or a welding helmet on grind setting.)
7. Leather welding gloves must be worn when operating equipment, handling material, and while welding. THIS INCLUDES WHILE GRINDING WITH AN ANGLE GRINDER.

The student must work and act in a manner that ensures individual safety and the safety of other students and the instructors.

1. Students must report all accidents and incidents, even minor, to their instructor immediately.
2. Students will be professional in their interactions with their instructor and other students.
3. Students shall not be under the influence of any drugs or alcohol, unless it is approved by a medical professional, per the Student Conduct Code.
4. The student shall not operate any equipment until the instructor, or his designee has given them proper training.

5. There is absolutely no horseplay allowed in the Lab at any time. This includes any deliberate unsafe act.

Any student who does not follow the proper safety or conduct procedures will have the following consequences.

1. Student will be given a verbal warning.
2. A second verbal warning will be given, an email will be sent to them explaining the violation, and student will re-sign the safety agreement.
3. Student will be given a third warning and referred to the student code of conduct office.
4. Continuing to disregard safety can result in either a 10% grade reduction and/or expulsion from the program.

My signature below indicates I have read and understand the safety and conduct requirements of the Welding Technologies Program.

CHAPTER 6.

ASSIGNMENT: UNDERSTANDING SAFETY

The purpose of this assignment is to assess your understanding of welding safety principles, hazards, and best practices, and to encourage critical thinking about safety measures within a welding environment.

TASK

Answer the following questions based on your knowledge of welding safety. Provide clear and concise responses.

1. What are the primary health risks associated with exposure to welding fumes? How can welders protect themselves from these risks?
2. Describe at least three types of personal protective equipment (PPE) essential for safe welding operations. Explain why each piece of PPE is necessary.
3. How does proper ventilation contribute to welding safety? Briefly explain the importance of effective ventilation in a welding environment.
4. Identify three common fire hazards in a welding area and describe preventive measures to mitigate these risks.
5. Discuss the importance of conducting inspections of welding equipment prior to using them. What aspects of the equipment should you inspect before starting a welding task?

Please refer to your course materials, lectures, and relevant resources to provide accurate and well-informed answers to the questions. If you encounter any difficulties or have questions, feel free to reach out to your instructor for clarification.

CRITERIA FOR SUCCESS

This assignment will be assessed based on the accuracy and depth of your responses, as well as your ability to apply safety principles to real-world scenarios. Demonstrating a solid understanding of welding safety concepts and practices will contribute to a higher grade.

PART II.

WIRE FEED EQUIPMENT

This module will focus on the fundamental aspects of wire feed welding equipment, exploring its components, functions, applications, and the crucial role it plays in modern welding practices.

Wire feed welding equipment, also known as wire welding machines, are used in various welding processes where a continuous electrode wire is fed into the weld pool to create a strong bond between metal pieces. Wire feed welding equipment is designed for specific welding processes and applications. The choice of equipment depends on factors such as the welding process, material type, joint configuration, thickness, and desired productivity. It's important to select the appropriate equipment and set it up correctly to achieve high-quality welds efficiently and safely. The types of equipment we'll be focusing on are *gas metal arc welding* (GMAW) equipment and *flux-cored arc welding* (FCAW) equipment.

LEARNING OBJECTIVES

By the end of this module you should be able to demonstrate the following skills:

- Select and safely set up gas metal arc welding equipment
- Store, transport, and handle all types of gas metal arc welding equipment properly and safely
- Use proper gas metal arc welding tools and equipment to weld

OR

- Select and safely set up flux core welding equipment
- Store, transport, and handle all types of flux core welding equipment properly and safely
- Use proper welding tools and equipment to weld using the flux core welding process

CHAPTER 7.

GAS METAL ARC WELDING EQUIPMENT

Gas metal arc welding (GMAW) equipment is designed for the GMAW welding process, which involves the use of a continuous electrode wire and a shielding gas to create strong and clean welds. GMAW welding is versatile and widely used for various applications. Here's a detailed description of GMAW welding equipment components and their functions:

POWER SOURCE

The power source is the heart of the GMAW welding equipment. It provides the electrical energy needed to create the welding arc and melt the electrode wire. Modern power sources are available in various sizes and types, including traditional transformer-based, inverter-based, and synergic control models. Synergic control power sources automatically adjust voltage and wire feed speed based on the selected settings, making setup easier.

WIRE FEEDER

The wire feeder is responsible for delivering the electrode wire to the welding torch at a consistent and controlled speed. It usually consists of a spool holder for the welding wire, a drive mechanism (usually a set of rollers), and a wire feed motor. The wire feeder's speed is synchronized with the power source's output to ensure proper welding parameters.

WELDING TORCH OR GUN

The welding torch or gun is held by the welder and directs the electrode wire into the weld pool. It contains a trigger that controls the wire feed, a gas nozzle that directs the shielding gas, and contact tips that guide the electrode wire. The torch may also have additional features like a gas diffuser, liner, and heat-resistant handle.

GAS SUPPLY SYSTEM

GMAW welding requires a shielding gas to protect the weld pool from atmospheric contamination. Common shielding gases include argon, carbon dioxide, and mixtures of both. The gas supply system consists of a gas cylinder, pressure regulator, flowmeter, and hoses that deliver the shielding gas to the welding torch.

GROUND CLAMP OR WORK CABLE

The ground clamp is attached to the workpiece and completes the electrical circuit necessary for the welding process. It ensures a safe and efficient flow of electricity from the power source to the workpiece.

CONTROL PANEL

The control panel on the GMAW welding equipment allows the welder to adjust various welding parameters. Parameters include voltage, wire feed speed, and sometimes synergic presets based on material type and thickness.

COOLING SYSTEM (OPTIONAL)

Some GMAW welding equipment models include built-in cooling systems to prevent the equipment from overheating during prolonged use. Cooling systems use fans and coolant to regulate the equipment's temperature.

SAFETY FEATURES

Modern GMAW welding equipment often includes safety features such as overload protection, thermal shut-off, and voltage reduction devices. These features enhance user safety and protect the equipment from damage due to excessive use or unfavorable conditions.

When using GMAW welding equipment, it's important to ensure proper setup, maintain cleanliness in the equipment, and follow safety guidelines to achieve high-quality welds while keeping the welder and the surrounding environment safe.

CHAPTER 8.

FLUX-CORED ARC WELDING EQUIPMENT

Flux-cored arc welding (FCAW) equipment is used for both self-shielded and gas-shielded flux-cored arc welding processes. Self-shielded FCAW equipment does not require external shielding gas, as the electrode wire contains flux materials that generate a shielding gas when heated. Gas-shielded FCAW equipment uses external shielding gases to protect the weld pool.

FCAW equipment is designed for the FCAW process, which is a variation of the arc welding process that uses a continuously fed electrode wire with flux materials inside. The flux produces a shielding gas when heated, which protects the weld pool from atmospheric contamination. FCAW equipment is versatile and used for a variety of applications, including both self-shielded and gas-shielded processes. Here's a detailed description of flux-cored arc welding equipment components and their functions:

POWER SOURCE

The power source supplies the electrical energy required to create the welding arc and melt the electrode wire. Similar to MIG welding equipment, FCAW equipment may use various types of power sources, including traditional transformer-based and inverter-based models.

WIRE FEEDER

The wire feeder in FCAW equipment is responsible for advancing the electrode wire to the welding torch at a controlled rate. It includes a spool holder for the flux-cored wire, a drive mechanism (rollers or push-pull system), and a wire feed motor. The wire feeder's speed is synchronized with the power source's output to maintain proper welding parameters.

WELDING TORCH OR GUN

The welding torch or gun directs the electrode wire into the weld pool, similar to other arc welding processes. It contains a trigger for wire feed control, a nozzle for directing the shielding gas (in gas-shielded FCAW), and contact tips. In self-shielded FCAW, the flux inside the wire generates a protective slag that shields the weld pool.

GAS SUPPLY SYSTEM (IN GAS-SHIELDED FCAW)

Gas-shielded FCAW uses an external shielding gas to protect the weld pool from atmospheric contamination. The gas supply system consists of a gas cylinder, pressure regulator, flowmeter, hoses, and a nozzle that delivers the shielding gas to the welding torch.

GROUND CLAMP OR WORK CABLE

Similar to other arc welding processes, the ground clamp is attached to the workpiece to complete the electrical circuit.

CONTROL PANEL

The control panel on FCAW equipment allows the welder to adjust welding parameters, including wire feed speed, voltage, and other settings.

COOLING SYSTEM (OPTIONAL)

Some FCAW equipment models feature built-in cooling systems to prevent overheating during extended welding sessions. Cooling systems typically involve fans and coolant to regulate the equipment's temperature.

SAFETY FEATURES

Modern FCAW equipment often incorporates safety features such as overload protection, thermal shut-off, and voltage reduction devices to enhance user safety and protect the equipment.

DUAL-PURPOSE FCAW EQUIPMENT

Some FCAW equipment models are designed to accommodate both self-shielded and gas-shielded processes. They allow welders to switch between the two methods based on the specific application.

When using FCAW equipment, it's essential to follow proper setup procedures, ensure a clean welding environment, and adhere to safety guidelines to achieve high-quality welds and maintain a safe working environment.

CHAPTER 9.

CAREER SPOTLIGHT: STRUCTURAL WELDER

A structural welder is a skilled professional responsible for joining metal components to create structural frameworks, assemblies, and large-scale constructions. This role is critical in various industries, including construction, manufacturing, infrastructure development, and more. Structural welders play a vital part in ensuring the stability, integrity, and safety of the structures they work on. Read on to learn more about the key responsibilities of structural welders.

WELDING OPERATIONS

Structural welders primarily use wirefeed welding techniques (GMAW/MIG) to join metal components, such as beams, columns, plates, and pipes, according to specified blueprints, welding procedures, and project requirements.

BLUEPRINT INTERPRETATION

They carefully read and interpret detailed blueprints, engineering drawings, and welding symbols to determine the correct welding positions, dimensions, and other specifications for each weld joint.

PREPARATION AND SET-UP

Before welding, structural welders prepare materials by cutting, grinding, and cleaning metal surfaces to ensure proper fit-up and optimal welding conditions. They may use hand and power tools for these tasks.

EQUIPMENT OPERATION

Structural welders operate welding equipment, including MIG welding machines, regulators, torches, and related tools. They adjust parameters such as voltage, wire feed speed, and gas flow to achieve precise and consistent welds.

SAFETY COMPLIANCE

Safety is paramount in structural welding. Welders adhere to safety protocols, including wearing appropriate personal protective equipment (PPE), maintaining a clean work area, and following safety guidelines to prevent accidents.

QUALITY ASSURANCE

Structural welders conduct visual inspections of their welds, checking for proper penetration, fusion, and quality. They address any defects, discontinuities, or imperfections to ensure weld integrity.

WELD QUALITY

They ensure that welds meet industry standards and specifications, considering factors like joint design, material type, and thickness. Structural welders contribute to the durability and load-bearing capacity of the structures they work on.

COLLABORATION

Structural welders often work as part of a team alongside other skilled tradespeople, such as fabricators, fitters, and engineers. Effective communication and collaboration are crucial for project success.

DOCUMENTATION

They maintain accurate records of welding procedures, materials used, inspection results, and any deviations from project specifications. Proper documentation helps track project progress and ensures compliance.

A structural welder can further advance in their career by gaining additional certifications, specializing in specific welding techniques, or pursuing supervisory roles. With experience, they may transition into roles such as welding inspector, foreman, or even become welding instructors to pass on their expertise to the next generation of welders. The demand for skilled structural welders remains strong across industries involved in construction, manufacturing, and infrastructure development.

CHAPTER 10.

ASSIGNMENT: WIRE FEED EQUIPMENT

The purpose of this assignment is to assess your understanding of wire feed welding equipment, its components, functions, and applications. This assignment aims to evaluate your knowledge of the equipment's role in various welding processes and its significance in achieving quality welds.

TASK

Answer the following questions based on your knowledge of wire feed welding equipment. Provide clear and concise responses.

1. What are the main pieces of welding equipment for wire feed? How does this equipment differ from other types of welding equipment?
2. How does a wire feeder work, and what is its role in wire feed welding?
3. Explain the importance of selecting the appropriate shielding gas for gas-shielded wire feed welding processes. Provide an example of when each type of shielding gas (e.g., argon, CO2) might be used.
4. Describe at least three safety considerations that should be taken into account when operating wire feed welding equipment. Explain the potential consequences of neglecting these safety practices.
5. In which industries or applications is wire feed welding equipment commonly used? Provide specific examples and explain why this type of equipment is suitable for those applications.

Please refer to your course materials, lectures, and relevant resources to provide accurate and well-informed answers to the questions. If you encounter any difficulties or have questions, feel free to reach out to your instructor for clarification.

CRITERIA FOR SUCCESS

This assignment will be assessed based on the accuracy and depth of your responses, as well as your ability to apply wire feed welding equipment knowledge to real-world scenarios. Demonstrating a solid understanding of welding wire feed equipment concepts and practices will contribute to a higher grade.

PART III.

GAS METAL ARC WELDING

Gas metal arc (GMAW) welding, also known as *metal inert gas* (MIG), *metal active gas* (MAG) or *hardwire welding*, is a versatile and widely used welding technique that offers speed, efficiency, and flexibility in joining various metals. Mastering GMAW welding procedures is essential for achieving strong, high-quality welds.

This chapter will:

- Walk you through the key steps and considerations involved in successful GMAW welding procedures
- Teach you how to identify and address common welding issues, such as poor fusion, porosity, and excessive spatter
- Explain quality control techniques to ensure your welds meet the required standards

LEARNING OBJECTIVES

By the end of this section you should be able to demonstrate the following skills:

- The different procedures used in GMAW

CHAPTER 11.

GMAW PROCEDURES BY JOINT TYPE

Gas metal arc welding (GMAW), commonly known as *metal inert gas* (MIG) welding, is a versatile welding process used to join various types of joints. The specific procedures and techniques used for welding different types of joints with GMAW depend on factors such as joint configuration, material type and thickness, welding position, and intended application. Here are the procedures for welding different types of joints with GMAW:

BUTT JOINT

- Clean the joint surfaces to remove any contaminants, rust, or paint.
- Set the appropriate welding parameters, including voltage, amperage, wire feed speed, and shielding gas flow rate.
- Position the torch at a 90-degree angle to the joint.
- Begin the weld at the joint's root and create a series of overlapping weld beads along the joint's length.
- Use a weaving motion to evenly distribute the weld bead and avoid excessive heat buildup.
- Maintain a consistent travel speed and adjust the torch angle to ensure proper penetration and fusion.
- Control the size of the weld bead to match the joint thickness and desired weld strength.

T-JOINT

- Position the torch perpendicular to the joint's intersection.
- Start the weld at the root of the joint and move in a straight line along the length of the joint.
- Use a weaving motion if necessary to achieve proper fusion on both sides of the T-joint.
- Control the torch angle to ensure adequate penetration and fusion at the joint's base.
- Maintain a steady travel speed and adjust parameters based on joint thickness.

LAP JOINT

- Position the torch at a slight angle to the joint's overlap, allowing the weld metal to bridge both sides.
- Begin the weld at the edge of the overlap and move in a straight line along the length of the joint.
- Apply the appropriate weaving motion if necessary to ensure proper fusion on both sides of

the lap joint.

- Control the torch angle to achieve adequate penetration and fusion between the overlapping pieces.
- Adjust parameters based on the thickness of the overlapping material.

CORNER JOINT

- Position the torch at a 45-degree angle to the joint's corner, directing the arc toward the intersection of the two pieces.
- Begin the weld at the joint's root and move in a circular motion along the joint's perimeter.
- Maintain proper torch angle to ensure penetration into both pieces and proper fusion.
- Adjust parameters based on the material thickness and joint configuration.
- Use weaving or oscillating motions as needed to achieve uniform weld bead distribution.

FILLET JOINT

- Position the torch at a 45-degree angle to the joint, directing the arc toward the thicker of the two pieces.
- Start the weld at the joint's root and create a weld bead along the length of the joint.
- Maintain a steady travel speed and use weaving motions to achieve even fusion on both sides of the joint.
- Adjust the torch angle to ensure proper penetration into both pieces.
- Control the size of the weld bead to match the joint thickness and desired strength.

Remember that proper preparation, parameter adjustments, torch manipulation, and technique play a crucial role in achieving quality welds in different types of joints with GMAW. It's essential to follow welding procedure specifications, industry standards, and the guidance of experienced professionals for the best results.

CHAPTER 12.

CAREER SPOTLIGHT: SHIPYARD WELDER

Shipyard welders are skilled professionals who play a crucial role in the construction, repair, and maintenance of maritime vessels such as ships, boats, and submarines. They use their welding expertise to join metal components, ensure structural integrity, and contribute to the safe and efficient operation of these vessels. Shipyard welders work in shipyards, which are facilities dedicated to shipbuilding and repair. Here's what shipyard welders do:

WELDING AND JOINING

Shipyard welders use various welding techniques, such as arc welding, MIG welding, TIG welding, and flux-cored arc welding, to join metal parts together. They create strong and durable welds that can withstand the challenges of a marine environment, including exposure to water, corrosion, and mechanical stresses.

STRUCTURAL FABRICATION

Shipyard welders assemble and fabricate the structural components of vessels, including hulls, decks, frames, and bulkheads. They ensure that these components fit together accurately and securely, contributing to the vessel's overall stability and safety.

PIPE WELDING

Shipyard welders are responsible for welding pipes and pipelines that transport fluids, gases, and other materials within the vessel. This includes systems for fuel, water, sewage, and more. Accurate and leak-free pipe welding is crucial to the vessel's functionality.

REPAIR AND MAINTENANCE

Shipyard welders are involved in repairing and maintaining vessels to extend their lifespan and ensure operational readiness. They inspect for corrosion, cracks, and other defects, and then carry out necessary welding repairs to restore the vessel's structural integrity.

BLUEPRINT READING

Shipyard welders read and interpret technical drawings, blueprints, and welding symbols to understand the specifications and requirements of each welding project. This ensures that they follow the correct welding procedures and dimensions.

MATERIAL SELECTION

Shipyard welders choose appropriate welding methods and materials based on the type of metal being used, the vessel’s function, and the marine conditions it will face. They consider factors like corrosion resistance, strength, and durability.

CHAPTER 13.

GMAW MATERIALS

GMAW can be used with a variety of materials.

CARBON STEEL

Carbon steel welding with spray transfer can be performed using a 95% to 98% Ar and 2% to 5% O2 mixture. Adding oxygen to the shielding gas mixture provides a more stable arc, minimizes undercutting, and permits faster travel speeds. Straight CO2 may be used for high-speed production welding. However, straight CO2 produces globular transfer with excessive spatter. *Pulsed spray transfer* (GMAW-P) can be performed with 90% Ar and 10% CO2.

Welding parameters such as electrode diameter, proper wire feed speed (current) and voltage, and shielding gas flow are set based on the carbon steel thickness.

ALUMINUM

Welding aluminum is a difference experience to other materials: it has a lower melting point (approximately 1200° F), its thermal conductivity is five times greater than steel, it does not change color as its temperature changes, and oxide on the surface melts at a higher temperature than the base metal (3700° F versus 1200° F). Aluminum is normally welded with GMAW, for thicknesses over 1/8″, or *gas tungsten arc welding* (GTAW) for thin (less than 3/16″) or intricate parts.

- Either constant current or constant voltage power sources can be used for GMAW work on aluminum.
- *Direct current electrode positive* (DCEP) or "reverse" polarity is used.
- For the shielding gas, 100% argon is most common, although helium or mixtures of argon and helium can be used.
- Gas flow rate should be between 25 and 40 cubic feet per hour.
- Either push pull systems or spool guns can be used as wire feeders, although only a pull/forehand travel should be used.
- Weaves are not recommended, due to the lack of cleaning action.
- Be aware when welding aluminum that the puddle is very soft and must be within certain parameters. Aluminum is also more prone to crater cracks.

Using short circuiting transfer on aluminum produces a colder arc than is produced with spray transfer, permitting the weld pool to solidify rapidly. This action is especially useful for vertical, overhead, and horizontal welding and for welding thin aluminum. When using GMAW in vertical position, a downhill technique is preferred.

Spray transfer on aluminum is especially suitable for thick sections. With spray transfer, more heat is produced to melt the electrode and the base metal. Vertical, horizontal, and overhead welds are typically more difficult with spray transfer than with short circuiting transfer.

Welding parameters such as edge preparation, electrode diameter, argon flow, proper current and voltage, and electrode feed speed for short circuiting transfer or spray transfer should be set based on aluminum thickness. In general, gas flow should be about 35, voltage at 24, and current at 180.

STAINLESS STEEL

Stainless steel was initially developed to prevent the rusting and corrosion that occurred with carbon steel. Stainless steel is produced at a higher quality level than carbon steels and has fewer impurities, making it a reliable material for welding.

On stainless steel 1/4″ thick or more, the welding gun should be moved back and forth with a slight side-to-side movement. Thin stainless steel is best welded with a slight back-and-forth motion along the joint. The forehand technique is generally used for welding stainless steel.

Short circuiting transfer can be used on thin stainless steel in overhead or vertical position. Spray transfer with stainless steel is not possible in overhead or vertical positions.

Quality welds can be produced on stainless steel using the spray transfer process with a 1/16″ diameter electrode and high current. DCEP with argon and 1% to 2% O2 may be used for spray transfer on stainless steel. Proper ventilation is necessary to remove the fumes.

Welding parameters such as edge preparation, electrode diameter, shielding gas flow, proper current and voltage, electrode feed speed, welding speed, and welding passes for short circuiting transfer or spray transfer should be set based on stainless steel thickness.

COPPER

Steel backing bars are required for welding copper 1/8″ thick or less. Preheating at this thickness is not necessary. Preheating at 400°F is advisable on sections 3/8″ thick or more.

Welding parameters such as edge preparation, electrode diameter, proper current and voltage, electrode feed speed, and welding speed should be set based on copper thickness.

CHAPTER 14.

CAREER CONNECTION: GMAW IN DIFFERENT INDUSTRIES

Gas metal arc welding (GMAW), commonly known as *metal inert gas* (MIG) welding, is widely used across various industries due to its versatility, ease of use, and ability to produce high-quality welds. Read below to learn more about some careers in which GMAW welding is often used.

AUTOMOTIVE MANUFACTURING AND REPAIR

GMAW welding is extensively used in the automotive industry for assembling and repairing vehicle frames, body panels, exhaust systems, and other components. Its ability to create strong, clean welds on various materials makes it a staple in car manufacturing and repair shops.

METAL FABRICATION

GMAW is a common choice for metal fabrication shops where various products are manufactured from metal components. This includes items like machinery, equipment, structural components, and architectural elements.

AEROSPACE INDUSTRY

GMAW is employed in aerospace manufacturing to create precise and high-quality welds on aircraft components, such as fuselage sections, engine parts, and landing gear.

CONSTRUCTION

GMAW welding is used in construction to join structural steel, beams, columns, and other components in buildings, bridges, and infrastructure projects.

HEAVY EQUIPMENT MANUFACTURING

Industries that produce heavy machinery and equipment, such as mining, agriculture, and construction, rely on GMAW for creating durable welds on large and sturdy components.

SHIPBUILDING

GMAW welding is used in shipyards to assemble and weld various sections of ships, including hulls, decks, and superstructures.

APPLIANCE MANUFACTURING

GMAW is used to create welds on various household appliances, such as refrigerators, ovens, washing machines, and water heaters.

FABRICATION OF SMALL AND MEDIUM-SIZED COMPONENTS

GMAW is suitable for both large-scale and smaller-scale production, making it applicable in workshops and factories that produce a wide range of products.

FURNITURE MANUFACTURING

GMAW is used in the production of metal furniture, where precise and clean welds are essential for both aesthetics and structural integrity.

RAILROAD INDUSTRY

GMAW welding is used in the manufacture and repair of railcars, locomotives, and railway infrastructure components.

CHAPTER 15.

GMAW DEFECTS AND DISCONTINUITIES

A *discontinuity* is an interruption of the typical structure of a material, such as a lack of its mechanical, metallurgical, or physical characteristics; any change to the normal pattern of work. A *defect* is a flaw in a part or product that is unable to meet minimum acceptance standards. The part or product can be rejected. Defects need to be either repaired or thrown away. All defects are discontinuities, but not all discontinuities are defects.

To ensure high-quality GMAW welding, follow proper welding procedures, maintain good welding technique, and implement effective quality control measures. To reduce all chances of discontinuities and defects, ensure regular inspections, proper material preparation, appropriate welding parameters, and skilled welder training.

The most common defects and discontinuities in GMAW include:

OVERLAP

Overlap is the protrusion of weld metal beyond the weld toe or weld root. It usually occurs when the arc does not melt the base metal sufficiently, causing the weld pool to flow onto unwelded base metal without fusing. Often, overlap occurs when the weld pool is allowed to become too large.

To prevent overlap, the size of the weld pool can be reduced by increasing the travel speed or reducing the wire feed speed. Also, heat input can be increased.

POROSITY

Generally, surface porosity is the direct result of atmospheric contamination. Atmospheric contamination occurs if the shielding gas level is set either too low or too high. If the shielding gas level is too low, the air in the arc area is not fully displaced. If the shielding gas level to too high, it causes turbulence, which draws air into the weld zone. On occasion, porosity occurs if welding is performed in a windy area. Without a protective wind shield, the shielding gas envelope may be blown away, exposing the molten weld pool to the contaminating effects of the air.

Subsurface porosity is caused by moisture in the shielding gas, an excessive tip-to-work distance, or surface contamination such as rust, paint, dirt, or oil on the base metal.

To prevent porosity:

- Work with clean material and well-maintained equipment
- Don’t use excessive current or arc length
- Change things like gas flow rate and purity
- Reduce travel speed
- Don’t forget to turn gas on before you start welding

CRATER CRACKS

Possible causes of cracks include moisture in the shielding gas, excessive tip-to-work distance, improperly filled concave craters, and contaminants such as rust, paint, dirt, or oil on the base metal.

INSUFFICIENT PENETRATION

Insufficient penetration (lack of penetration) is due to low heat input in the weld area, failure to keep the arc properly located on the leading edge of the weld pool, or traveling too fast. If the heat input is too low, increase the wire feed speed to increase the welding current.

EXCESSIVE PENETRATION

Excessive penetration (excessive melt-through) is caused by excessive heat in the weld zone or too wide a root opening. Excessive penetration results in a weld root bead that protrudes below the bottom of the joint.

Problems with excessive penetration can be minimized by reducing the wire feed speed, which lowers the current, or by increasing the travel speed. Too wide a root opening can be compensated for by increasing electrode extension and depositing the root pass with a weaving motion.

WHISKERS

Whiskers are short lengths of electrode wire sticking through the weld joint. Whiskers are caused by pushing the wire past the leading edge of the weld pool. A small section of wire protrudes inside the joint and becomes welded to the deposited metal.

To remedy this defect, reduce the travel speed, increase the contact tip-to-work distance slightly, or reduce the wire feed speed.

CHAPTER 16.

GMAW DISTORTION CONTROL

Distortion is the same thing as warping. In the past, the terms “warpage” or ‘warping” were typically used. Nowadays, people tend to say “distortion.” When metal gets hot it expands, when it cools down it shrinks. If metal heats and cools unevenly, it will expand and contract unevenly (distortion). Metal will always distort towards the heat.

Not all metals distort the same way. How much metal distorts depends on how well it conducts heat and how fast it expands. Under the same circumstances, stainless steel will distort more than carbon steel because stainless has lower thermal conductivity (it conducts less heat) and it expands faster.

You cannot totally prevent distortion, but it can be controlled to an “acceptable level”. An acceptable level of distortion will not compromise the integrity of the weld.

METHODS OF DISTORTION CONTROL

- Restraint: physically hold the metal in place as you weld.
- Sequencing: start with offset plates, then weld in a sequence in which the plates straighten out as you weld.
  - Finding the proper sequencing order is often done by trial and error.
- Minimizing welding: use staggered instead of intermittent welds.
  - Why does this work? Welding creates heat. Heat causes distortion. If you can weld less, there will be less heat and distortion.
- Proper joint preparation: put tack welds in the right places.
- Best fit-up: measure before you weld.
- Higher welding speed: don’t let heat get concentrated.
  - This is especially useful and important when welding with aluminum!
- Make fewer passes.
- Offset parts: start crooked so it straightens out as you weld.
  - Some welds you cannot tack multiple sides.
- Peen the weld metal: this causes the metal to stretch, offsetting contractions.
- Heat sinks: use water or an aluminum block to cool your metal
- Flame bending: apply heat to a distorted section to reverse distortion.

CHAPTER 17.

ASSIGNMENT: UNDERSTANDING GMAW PROCEDURES

The purpose of this assignment is to assess your understanding of GMAW procedures.

TASK

Answer the following questions. Provide clear and concise responses.

1. How does GMAW differ from GTAW?
2. At what work angle should the welding gun be held for horizontal fillet welding?
3. At what work angle should the welding gun be held for flat fillet welding?
4. What determines whether a pulling or pushing technique should be used?
5. What is the difference between spray transfer and globular transfer?
6. Why is globular transfer ineffective for welding heavy-gauge metals?
7. What is meant by short circuiting transfer? For what type of welding is this most effective?
8. What is the probable cause for the formation of overlap in a weld?
9. What should be done to prevent surface porosity in a weld?
10. How can crater porosity or cracks be prevented?
11. What should be done if weld penetration is insufficient?

Please refer to your course materials, lectures, and relevant resources to provide accurate and well-informed answers to the questions. If you encounter any difficulties or have questions, feel free to reach out to your instructor for clarification.

CRITERIA FOR SUCCESS

This assignment will be assessed based on the accuracy and depth of your responses, as well as your ability to apply knowledge of GMAW procedures to real-world scenarios. Demonstrating a solid understanding of GMAW concepts and practices will contribute to a higher grade.

CHAPTER 18.

ASSIGNMENT: UNDERSTANDING GMAW APPLICATIONS

The purpose of this assignment is to assess your understanding of GMAW applications.

TASK

Answer the following questions. Provide clear and concise responses.

1. When welding carbon steels. what thickness range may be butt welded with no edge preparation?
2. What type of joint is required for carbon steel greater than 1″ thick?
3. Which shielding gas mixture is recommended for welding carbon steels?
4. Why is spray transfer preferred for welding thick sections of aluminum?
5. Which technique should be used for GMAW in vertical position?
6. What type of backing is required when welding stainless steel?
7. What type of backing is required when welding copper?
8. When should preheating be used on copper?

Please refer to your course materials, lectures, and relevant resources to provide accurate and well-informed answers to the questions. If you encounter any difficulties or have questions, feel free to reach out to your instructor for clarification.

CRITERIA FOR SUCCESS

This assignment will be assessed based on the accuracy and depth of your responses, as well as your ability to apply GMAW knowledge to real-world scenarios. Demonstrating a solid understanding of GMAW concepts and practices will contribute to a higher grade.

CHAPTER 19.

ASSIGNMENT: UNDERSTANDING GMAW DEFECTS AND DISCONTINUITIES

The purpose of this assignment is to assess your understanding of GMAW defects and discontinuities: what they are, what causes them, and how they can be prevented.

TASK

Answer the following questions. Provide clear and concise responses.

1. How do crater cracks form?
2. How can crater cracks be prevented?
3. What causes toe cracks?
4. What are the two main types of porosity?
5. What can be done to reduce porosity in a weld?
6. What are slag inclusions?
7. How can slag inclusions be prevented in multiple pass welds?
8. Which process is more likely to produce incomplete fusion: SMAW or GMAW in short circuiting mode, and why?
9. What causes incomplete penetration?
10. What is overlap, and how can it be prevented?

Please refer to your course materials, lectures, and relevant resources to provide accurate and well-informed answers to the questions. If you encounter any difficulties or have questions, feel free to reach out to your instructor for clarification.

CRITERIA FOR SUCCESS

This assignment will be assessed based on the accuracy and depth of your responses, as well as your ability to apply knowledge of GMAW defects and discontinuities to real-world scenarios. Demonstrating a solid understanding of GMAW defects and discontinuities will contribute to a higher grade.

PART IV.

FLUX-CORED ARC WELDING

Flux-cored arc welding (FCAW) is a welding process that uses a continuously fed electrode containing flux to create a weld. FCAW is commonly used in construction, shipbuilding, offshore, and heavy fabrication industries.

This section will:

- Walk you through the key steps and considerations involved in successful FCAW welding procedures
- Teach you how to identify and address common welding issues, such as poor fusion, porosity, and excessive spatter
- Explain quality control techniques to ensure your welds meet the required standards

LEARNING OBJECTIVES

By the end of this section you should be able to demonstrate the following skills:

- Execute the different procedures used in FCAW
- Describe common types of flux cored arc welding (FCAW) and list their advantages.
- List common types of FCAW equipment.
- Identify common applications of FCAW.

CHAPTER 20.

FCAW OVERVIEW

Flux cored arc welding (FCAW) is an arc welding process that uses a tubular electrode with flux in its core. FCAW is capable of high weld metal deposition rates and deep penetration. FCAW is very similar to GMAW with respect to operation and the type of equipment used. In FCAW, weld metal is transferred as in GMAW globular or spray transfer.

The flux cored arc welding process was developed in the 1950s with the development of an electrode that contained a core of powdered flux material. However, even with the flux cored electrode, an external shielding gas was required. In 1959, a flux cored electrode was developed that did not require an external shielding gas. Shielding gas could be generated solely by the flux contained in the core of the electrode as it was being consumed during the welding process. This reduced the cost of the welding process by eliminating the need for additional shielding gas and its accompanying equipment.

TYPES OF FCAW

- *Self-Shielded FCAW* (FCAW-S): In this process, the electrode's flux generates shielding gases when it decomposes during welding. This eliminates the need for external shielding gas and is commonly used for outdoor and field applications. FCAW-S is also called Innershield in the field, although Innershield specifically refers to a FCAW process developed by Lincoln.
- *Gas-Shielded FCAW* (FCAW-G): This process uses an external shielding gas, usually a mix of argon and carbon dioxide, to protect the weld pool from atmospheric contamination. FCAW-G typically provides better control over the welding process and produces cleaner welds.

Both FCAW-S and FCAW-G produce a slag coating over the weld to protect it from the atmosphere, although this slag is easily removed.

WELDING EQUIPMENT

Equipment for FCAW is similar to that used for GMAW. The required equipment includes a welding machine, a welding gun cable and gun assembly, a wire feeder with knurled drive rolls, flux cored electrode wire, and workpiece lead with a workpiece connection. Additionally, for FCAW-G, shielding gas and a shielding gas supply system are required.

- FCAW-S: Requires a welding machine capable of providing sufficient amperage to melt the electrode and produce the desired weld size.
- FCAW-G: Requires a welding machine with both voltage and wire feed speed control to regulate the arc and achieve proper penetration.

ELECTRODES AND FLUX

- FCAW-S: The electrode's flux generates shielding gases as it burns, eliminating the need for external shielding gas. The flux composition influences the welding characteristics and final weld quality.
- FCAW-G: The electrode's flux generates some shielding gas, but an additional external shielding gas is used to provide better arc stability and protect the weld pool.

SHIELDING GAS

- FCAW-G uses a mix of shielding gases, usually argon and carbon dioxide, to protect the weld pool. The gas composition affects the arc stability and weld quality.

CHAPTER 21.

FCAW TECHNIQUES

Remember that specific FCAW procedures may vary depending on the welding position, material type, and joint configuration. It's important to follow the manufacturer's recommendations, welding codes, and industry standards when performing FCAW. Additionally, practice and experience play a significant role in mastering FCAW procedures and achieving high-quality welds.

SAFETY PRECAUTIONS

- Wear appropriate *personal protective equipment* (PPE), including welding helmet, gloves, and clothing.
- Work in a well-ventilated area to avoid exposure to fumes and gases generated during welding.

FCAW electrode wires produces smoke and fumes. Some base metals can also produce toxic fumes when welded. Fume extraction equipment should be used to keep smoke and fumes from entering under the welder's helmet and to protect others who are working in the area. Some options to deal with fumes include:

- A fume extractor with a flexible hose arm can be positioned close to the fume source.
- It is good safety practice to use a welding helmet equipped with a respirator to protect the face, eyes, nose, and lungs from smoke and fumes.
- Specially designed welding guns are available with built-in fume extraction systems to evacuate smoke and fumes from the weld area while providing maximum visibility.

WELDING PARAMETERS

- Voltage: Controls the length and stability of the arc. Adjust to control penetration and bead shape.
- Wire Feed Speed: Determines the amount of filler metal deposited. Adjust to achieve the desired weld size and bead appearance.
- Travel Speed: Affects the weld size and heat input. Faster travel speeds result in less heat input, while slower speeds provide more heat input.
- Polarity: Typically used in *DC electrode positive* (DCEP) for better penetration and reduced spatter.

JOINT PREPARATION

- Clean and prepare the joint surfaces before welding to remove rust, paint, dirt, and contaminants.

- Proper joint geometry, including bevels or grooves, may be required for thicker materials to achieve proper penetration.

WELDING TECHNIQUE

- Maintain a consistent travel speed and arc length to produce even and smooth weld beads.
- Watch for proper fusion between the base metal and the filler metal.
- Use weaving or oscillation techniques for wider welds.
- A steady push or a Z-weave technique can be used for welding in the vertical position with uphill travel.
- When using the weave technique, move up the joint in small increments, and stop momentarily at each toe to prevent undercut.

POST-WELDING STEPS

- Inspect the weld for defects such as lack of fusion, porosity, and cracks.
- Clean the weld area to remove any slag or spatter.
- Depending on the application and material, consider performing post-weld heat treatment or stress relief to release residual stresses.

CHAPTER 22.

FCAW BENEFITS

The *flux cored arc welding* (FCAW) process combines the best qualities of *shielded metal arc welding* (SMAW), *submerged arc welding* (SAW), and *gas metal arc welding* (GMAW). FCAW combines the production efficiency of GMAW and the penetration of SMAW, produces a quality weld with less effort than SMAW and is more flexible than SAW.

FCAW uses fluxing agents that remove detrimental materials from the weld pool and improve the chemical and mechanical properties of the weld. The ability to manufacture FCAW electrode wires with different combinations of elements for specific applications makes FCAW an extremely versatile process. The most common application for FCAW is structural fabrication.

Some additional benefits of FCAW include the following:

- Enables the welder to weld continuously for long periods;
- Requires less pre-cleaning of base metals than GMAW;
- Produces less distortion than SMAW;
- Produces smooth, uniform beads with an excellent weld appearance;
- Has a high deposition rate (which makes FCAW popular in railroad, shipbuilding, and automotive industries);
- Is capable of relatively high travel speeds;
- Can be used to weld a variety of steels and a wide range of metal thicknesses.

In addition, FCAW can be used in all positions with the proper electrode and shielding gas, and can be used to weld carbon steels, low-alloy steels, various stainless steels, and high strength quenched and tempered steels.

CHAPTER 23.

FCAW DEFECTS AND DISCONTINUITIES

A *discontinuity* is an interruption of the typical structure of a material, such as a lack of its mechanical, metallurgical, or physical characteristics; any change to the normal pattern of work. A *defect* is a flaw in a part or product that is unable to meet minimum acceptance standards. The part or product can be rejected. Defects need to be either repaired or thrown away. All defects are discontinuities, but not all discontinuities are defects.

To ensure high-quality FCAW welding, follow proper welding procedures, maintain good welding technique, and implement effective quality control measures. To reduce all chances of discontinuities and defects, ensure regular inspections, proper material preparation, appropriate welding parameters, and skilled welder training.

The most common defects and discontinuities in FCAW include:

POROSITY

Porosity consists of cavity-type discontinuities formed by gas that gets stuck in the weld as it cools. Porosity is usually the least harmful type of weld discontinuity. Many fabrication standards and codes provide comparison charts that show the amount of acceptable porosity. If there is more porosity than allowed, it must be ground out and repaired. There are three types of porosity: surface porosity, subsurface porosity, and linear porosity.

Surface porosity consists of discrete round or elongated holes on the surface of the weld. Surface porosity is formed if dissolved gases cannot fully escape before the weld metal cools. Causes of surface porosity include not enough shielding gas coverage and too high gas flow rates that expose the molten weld to oxygen in the air.

Subsurface porosity consists of discrete round or elongated holes within the weld. The holes can be many different sizes, from microscopic to 1/8” diameter. There are three types of subsurface porosity: uniformly scattered, cluster, and linear. *Cluster porosity* voids occur in the form of clusters separated by considerable lengths of pore-free weld metal. Cluster porosity is associated with changes in welding conditions, such as stopping or starting of the arc. *Linear porosity* usually happens in a relatively straight line. Causes of linear porosity include insufficient shielding gas coverage and dirt, rust, or moisture on the base metal or welding consumables. Linear porosity is most likely to occur in the root pass

Prevention methods include:

- Improve welding housekeeping conditions that can cause the porosity
- Use clean materials and well-maintained equipment and properly align fans and drafts
- Avoid the use of excessive current and arc lengths
- Avoid high currents and excessive arc lengths

    - This may cause the de-oxidizing elements in the electrode to break down, so there won't be enough left to combine with the metal during cooling
- Change welding conditions such as gas flow rate and gas purity. This makes up for improper arc length, welding current, or electrode manipulation
- Reduce travel speed
- Turn on the gas before welding

WORMHOLES

Wormholes are elongated or tubular cavities caused by excessive entrapped gas. Wormholes have the appearance of sharply defined dark shadows of that are rounded or elongated. Wormhole porosity is the most severe type of porosity because it provides a leak path through the weld. This is especially serious when the vessel or pipe is intended to contain liquid.

To prevent wormholes:

- Use the same methods as those to prevent porosity
- Eliminate the gas and cavities

Methods of correcting wormholes include:

- Grinding
- Air gouging
- Rewelding

SLAG INCLUSION

Slag inclusions occur when bits of slag get trapped in a weld. *Slag* is a material made when flux and impurities in metal react together. It's not a metal and it forms during a chemical process when they mix. Slag inclusions aren't as heavy as the surrounding metal, so they usually rise to the surface of molten metal. Slag inclusions are detected by radiographic testing where they appear as dark lines parallel to the edges of the weld. Slag inclusions are usually elongated, rounded, and run in the direction of the of the weld. Slag inclusions can be continuous, intermittent, or randomly spaced.

Multiple-pass welds are more prone to slag inclusions than single-pass welds. Slag from the preceding pass, if not completely removed when cleaning, will become entrapped in the subsequent pass.

Slag inclusions are prevented by using proper welding preparation:

- Thoroughly remove slag from the weld
- Clean the weld between each pass of a multiple-pass weld
    - If you don't thoroughly remove slag between each pass, it increases the chances of slag entrapment and the production of a defective weld.

INCOMPLETE FUSION

Incomplete fusion is a lack of union (fusion) between adjacent weld passes or base metal. Incomplete fusion is usually elongated in the direction of welding, with either sharp or rounded edges. Causes of incomplete fusion include incorrect electrode manipulation by the welder and failure to heat the base metal or previously deposited weld metal to the melting temperature.

Incomplete fusion can be prevented or corrected by:

- Using proper settings depending on size of base metal
- Following weld sizes listed on the blueprint
- Paying attention to joint fit-up
- Grinding or air gouging of weld and rewelding

SPATTER

Spatter is a discontinuity consisting of metal particles expelled during fusion welding that do not form part of the weld. Spatter is not usually considered a serious discontinuity unless it impacts future operations. Only spatter which sticks to the base metal is a concern. Large globules of spatter can create a *heat-affected zone* (HAZ) on the base metal surface, which has a similar effect as an arc strike. Spatter on the base metal surface also creates stress, which could cause problems during service of the finished product. Spatter detection is achieved by visual examination (VT).

Spatter can be prevented or corrected by:

- Adding argon to the shielding gas mixture can drastically reduce spatter
- Using anti-spatter spray
    - Be careful: too much anti-spatter spray can cause other discontinuities like porosity
- Reducing the welding current and arc length

UNDERCUT

Undercut occurs when a groove melts in the base metal next to the toe of the weld but is not filled by the weld metal. It causes a weaker area at the toe of the weld and often leads to cracking. Low-thickness areas are often the first to crack under loading. Undercut can also decrease a joint's strength by trapping water and dirt. This makes corrosion happen faster.

Undercut can occur for several reasons:

- Excessive heat from high current and voltage settings
- Too fast of a travel speed and the electrode moves away from the weld pool prematurely
- Edges are not prepared properly
- Dirt or grit are present on the welding surfaces

It's important to use the proper welding current and voltage. Voltage, like current, is an indicator of the total heat input into the weld. When voltage goes up, more heat enters the weld zone, and more base metal melts Excess heat creates a larger than required cavity which is not always totally filled. This leads to undercuts on the sides of the weld due to a lack of filler material.

Undercut can be prevented or corrected by:

- Reduce amperage
- Reduce arc length
- Use correct electrode angle
- Adjust travel speed
- Grind out undercut and reweld

CHAPTER 24.

FCAW DISTORTION CONTROL

Distortion is the same thing as warping. In the past, the terms “warpage” or ‘warping” were typically used. Nowadays, people tend to say “distortion.” When metal gets hot it expands, when it cools down it shrinks. If metal heats and cools unevenly, it will expand and contract unevenly (distortion). Metal will always distort towards the heat.

Not all metals distort the same way. How much metal distorts depends on how well it conducts heat and how fast it expands. Under the same circumstances, stainless steel will distort more than carbon steel because stainless has lower thermal conductivity (it conducts less heat) and it expands faster.

You cannot totally prevent distortion, but it can be controlled to an “acceptable level”. An acceptable level of distortion will not compromise the integrity of the weld.

Distortion control is an important consideration in welding to ensure that the final welded structure or component maintains its desired shape and dimensions. *Flux cored arc welding* (FCAW) is a welding process that can be prone to distortion due to its high heat input and deposition rates. Here are some techniques to help control distortion when using FCAW:

- Weld Sequence Planning: Plan your weld sequence carefully to distribute the heat and distortion evenly. Start welding at the center and move outward, alternating sides to minimize the accumulation of heat in one area.
- Tack Welding: Use tack welds to hold parts in place before making full welds. This helps to secure the components and minimizes distortion during the welding process.
- Use Jigs and Fixtures: Employ jigs, fixtures, and clamps to hold parts in their intended positions. These tools can prevent movement during welding, reducing the likelihood of distortion.
- Preheat and Interpass Temperature Control: Preheating the base metal and controlling the interpass temperature can help reduce the overall temperature gradient, preventing excessive distortion. Follow recommended preheat and interpass temperature guidelines for the material being welded.
- Faster Welding Travel Speed: Faster travel speeds can reduce the heat input and allow the heat to dissipate more evenly. This can help control distortion, especially in thicker materials.
- Backstep Welding Technique: Utilize the *backstep* or *skip* welding technique, where you weld small sections and move backward. This approach minimizes the overall heat input and reduces distortion.
- Peening: Use *peening* (light hammering) immediately after welding to distribute residual stresses and reduce distortion. Be cautious not to cause surface damage.
- Stringer Bead Welding: Stringer bead welding (single pass) rather than wide-weave bead

welding can help reduce the amount of heat introduced and control distortion.

- Control Welding Direction: Consider welding uphill to help minimize distortion. Welding uphill provides better control over the heat distribution and cooling rate.
- Fixturing and Restraint: Strategically use fixturing and restraint to minimize warping. Adequate support and controlled restraint can help prevent undesired movement during welding.
- Post-Weld Heat Treatment: Depending on the material and the application, post-weld heat treatment (stress relieving) can be applied to release residual stresses and reduce distortion.
- Welding Techniques and Parameters: Adjust your welding parameters, such as voltage, current, and wire feed speed, to control heat input. Experiment with different techniques to find the optimal settings for distortion control.
- Monitor and Inspect: Regularly monitor the parts during welding to detect any signs of distortion. Inspect for alignment and dimensional changes, making adjustments as needed.

Remember that controlling distortion in welding involves a combination of proper planning, technique, and material-specific considerations. Experimentation and practice will help you identify the best distortion control strategies for your specific FCAW applications.

PART V.

BLUEPRINTS & WELDING SYMBOLS

Blueprints are tools used to communicate exactly what the engineer or architect wants done. Welders will most commonly refer to fabrication or shop drawing blueprints. Welding symbols are commonly used on blueprints as standardized visual representations of welded joints that communicate the information needed to precisely recreate the joint. This section will focus on how to read and interpret blueprints and welding symbols.

CHAPTER 25.

BLUEPRINTS

There are three main types of blueprint drawings: mechanical/engineering, architectural, and shop/fabrication. Welders will most often have to read and interpret shop or fabrication drawings. Drawings can be done in *isometric* view (a three-dimensional view showing three sides in a single drawing) or *orthographic* view (a two-dimensional view, requiring multiple views to show the whole of a part).

When using blueprints in the welding shop, remember that drawings are expensive to both produce and to copy. Do not write unauthorized notes on a drawing, always protect drawings from dirt and liquids, never fold a drawing, and be sure to store them in a safe, easily accessible area.

TYPES OF BLUEPRINTS

Mechanical or *engineering drawings* have been used for centuries (see: Leonardo da Vinci's notebooks). They are often a set or group of drawings and may contain various pages. Mechanical drawings are often used for bidding contracts or for developing fabrication drawings (the design of the building's skeleton, mechanical systems, electrical, ventilation, or plumbing systems).

Architectural drawings show the initial design of a structure. They allow architects to match what the customer wants, ensure the building looks good in its immediate surroundings, and check that the building meets building codes. Architectural drawings often show building elevation and floor plans.

Fabrication or *shop drawings* provide information to the fabricator (the person doing the construction). They include details on building individual parts, such as dimensions, connections, welds, holes or cuts, and finishing requirements. These drawings allow the fabricator to select the proper steel shapes and sizes from stock.

DIMENSIONS

The most important information on any drawing is probably the *dimensions*. These are numerical values that describe the size, location, geometric characteristics, or surface textures of various features. Dimensional *tolerances* show how much or how little you can deviate from the written value, and are usually expressed as +/- the maximum amount of deviation allowed. When creating a blueprint, always remember to:

- Place dimensions so it is easy to determine what is being measured,
- Avoid using different units of measure on the same blueprint (metric vs English, fractions vs decimals, etc.),
- Avoid running dimension or extension lines (see below) across or through each other, and
- Keep the drawing clean and easy to read.

TYPES OF LINES

Blueprints use different lines for different purposes. To review a few of the line types:

- Cutting plane lines: used to show imaginary cuts (that only exist in the blueprint, not in the actual part) to reveal more details
    - These lines are thick, with their ends at 90° and arrowheads showing direction from which the view is taken.
- Object or visible lines: used to outline visible edges and contours
    - These lines are thick and continuous.
- Hidden lines: used for hidden edges and internal features, such as the internal workings of a hollow object
    - These lines are medium weight, typically 1/4″ dashes separated by 1/16″ spaces.
- Center lines: used to show the center of symmetrical objects or features such as holes
    - These lines are fine and dark with alternating short and long dashes.
- Section lines: used to show interior features, cut surfaces, or the type of material being cut
    - These lines are typically fine and dark, but otherwise can vary depending on the company that drew the blueprint.
- Break lines: used to remove sections for clarity, to provide a clearer view of parts below the removed part, or to shorten long parts
    - Short break lines show a partial section, while long break lines show a shortened section of a longer part (to conserve paper space).
- Leaders and arrows: used to point out more details, an important idea, or otherwise add a note
    - These lines are fine with an arrowhead on only one end.
- Phantom lines: used to show adjacent positions of related parts, alternate positions of moving parts, repeated details, or filleted and rounded corners
    - These lines are thin and dark with long dashes alternating with pairs of short dashes.
- Dimension lines: used to indicate extent and direction of a dimension
    - These lines are capped on each end with arrowheads and placed between extension lines. The dimension is usually placed at the midpoint of the line and can show the tolerance with +/-.
- Extension lines: used to indicate the termination of a dimension
    - These lines have the same line weight as the dimension line.

CHAPTER 26.

BLUEPRINT LAYOUT

Most drawings will include the following parts: the title block, the bill of materials, an area for specifications, general notes, a reference drawing list, and a revision chart.

The title block will include the company name and logo as well as their contact information. It will also have the name of the object to be fabricated, and several other important pieces of information:

- Customer name, name of the engineering firm, and job or contract number
- Date and number of the drawing
- Scale for the drawing (see below)
- Any revisions

The bill of materials will have space for information on each material involved, including the item or mark number, quantities, material descriptions (structural shapes), grades of material, and weights.

SCALE

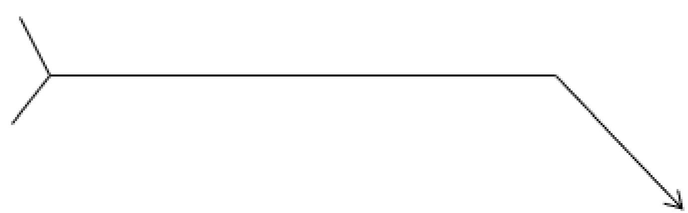
Objects too large to be drawn life-sized are scaled down to fit on the paper. They are kept proportional by using smaller units of measure; for example, a drawing might use one inch in place of one foot. Another scale might be 1/4″ equal to 1′, at which scale a four-foot-long object would be one inch long when drawn on paper. The scale is located in the title block of the drawing and used to check object sizing and dimensions. Scales are most common for printed blueprints or hand-drafted prints.

CHAPTER 27.

WELDING SYMBOLS

Welding symbols are used to record the specifics of a given weld. They are most often found on shop or fabrication drawings. AWS A2.4 – Standard Symbols for Welding, Brazing, and Nondestructive Examination is the official standard for all elements of the welding symbol.

The basic components of a welding symbol are the reference line (always required), arrow line, and tail. The *reference line* is always horizontal and forms the base of the welding symbol. The *arrow line* points to the line or lines on the drawing which clearly identify the proposed joint or weld area. One end has an arrow pointing towards the drawing and the other connects to one end of the reference line. The *tail*, the right-angled line on the other end of the reference line, is used to record any supplementary information about the weld, such as welding or cutting processes, specifications, or procedures.

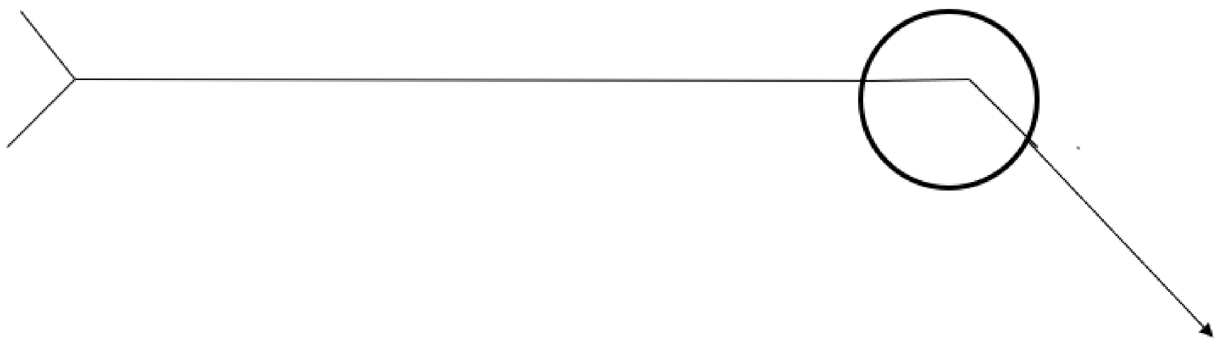


A welding symbol, from left to right: tail, reference line, arrow line.

When talking about a welding symbol, the *arrow side* is the side of the reference line where the arrow line is, while the other side of the reference line is simply called the *other side*. Any symbolism on the arrow side of a welding symbol applies to the part of the drawing that the arrow line is pointing at. Any symbolism on the other side applies to the other side of the same area, which the arrow line is not pointing at.

Other symbolism used in welding symbols includes:

- A circle around where the arrow and reference lines meet: welding all around the joint

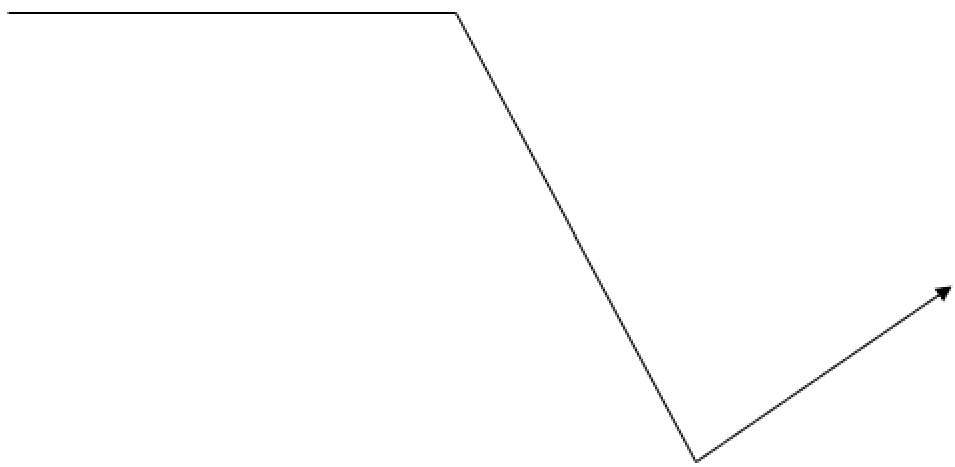


Welding all around the joint

- A black, triangular flag where the arrow and reference lines meet: field weld

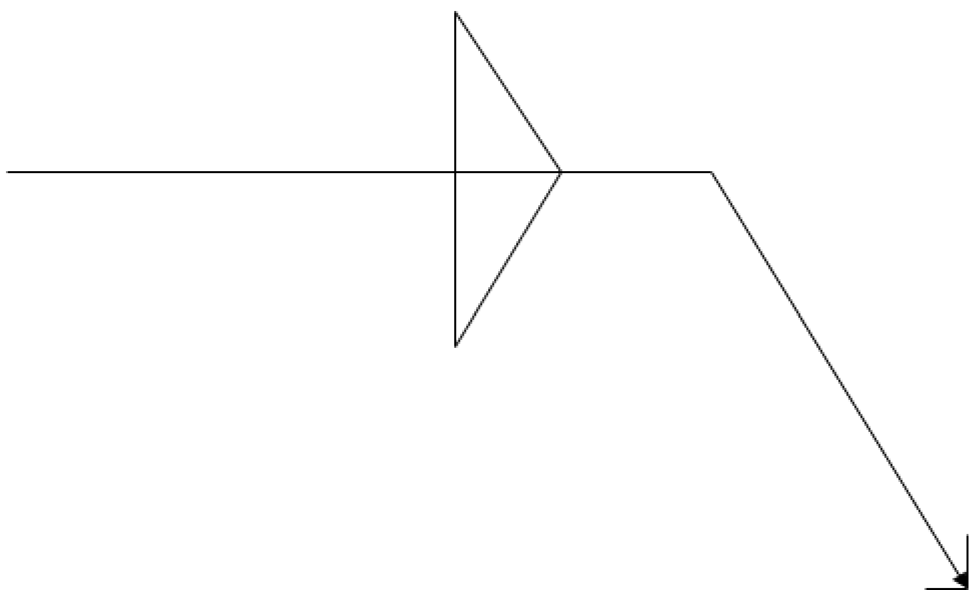
Field weld

- A break in the arrow line: arrow side must be side that receives beveling or other required preparations



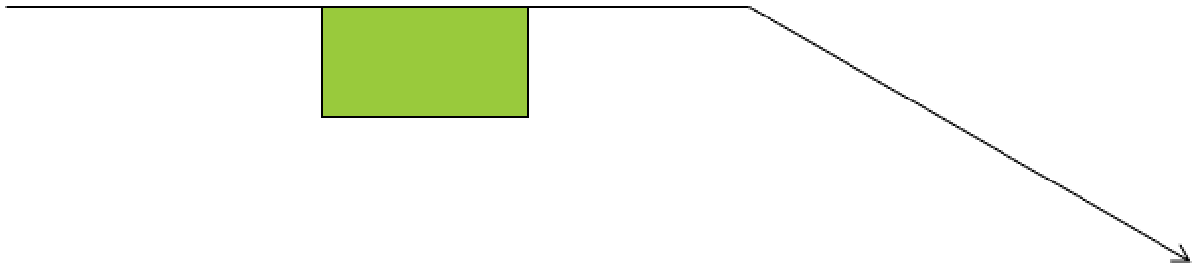
Arrow side receives beveling or other preparations

- A plain triangle off the reference line: filet weld



Filet welds on arrow side and other side

- A filled rectangle off the reference line: plug or slot weld



Plug or slot weld on arrow side

The relative locations of the symbols along the reference line can have meaning, such as staggered or intermittent welds along the welding area. Welding symbols can also include numbers to accurately convey information such as the depth of a bevel, the length of a weld, the number of spot welds to complete in an area, etc. If you're not sure what something on a welding symbol refers to, always look it up.

PART VI.

WIRE FEED LABS

This section will present various labs for students to practice their wire feed welding skills.

CHAPTER 28.

WEEK 1 LAB

Use a mixture of 75% argon and 25% carbon dioxide gas when welding with steel for these labs.

STRINGER BEADS ALL POSITIONS GMAW

Setup

Materials required are a single 3/16″ to 3/8″ thick steel plate measuring 3″ by 6″.
Positions required are 1G, 2G, 3G, and 4G.

Work

Weld 2 layers of surfacing beads on the plate. Each pair of layers should be completed in a different position.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- Half overlap over previous weld bead

CHAPTER 29.

WEEK 2 LABS

T-JOINT 1F MULTI-PASS GMAW

Setup

Materials required are two steel plates, each with thickness between 16 gauge and 1/8″ and measuring 1.5″ x 8″.

Position required is 1F.

Work

Create a t-joint with the given materials. Complete three passes total with one stop/start in the middle.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- No porosity

T-JOINT 3F MULTI-PASS GMAW

Setup

Materials required are two steel plates, each with thickness between 16 gauge and 1/8″ and measuring 1.5″ x 8″.

Position required is 3F.

Work

Create a t-joint with the given materials. Complete three passes total with one stop/start in the middle.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut

- Complete penetration
- No porosity

BUTT JOINT 1G GMAW

Setup

Materials required are two steel plates, each with thickness between 16 gauge and 1/8″ and measuring 1.5″ x 8″.

Position required is 1G.

Work

Create a butt joint with the given materials.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration

CHAPTER 30.

WEEK 3 LABS

T-JOINT 4F MULTI-PASS GMAW

Setup

Materials required are two steel plates, each with thickness between 16 gauge and 1/8″ and measuring 1.5″ x 8″.

Position required is 4F.

Work

Create a t-joint with the given materials. Complete three passes total with one stop/start in the middle.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- No porosity

LAP JOINT 1F GMAW

Setup

Materials required are two steel plates, each with thickness between 16 gauge and 1/8″ and measuring 1.5″ x 8″.

Positions allowed are 1F or 2F.

Work

Create a lap joint with the given materials.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration

BEADS ON PLATE 1G ALUMINUM

Setup

Materials required are a single 1/4″ thick aluminum plate measuring 4″ by 5″. You may use a spool gun or a push-pull gun for this lab.

Position required is 1G.

Work

Run surfacing beads to fill up the plate, then turn the plate 90° and run surfacing beads again. You must finish with two layers on the plate.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- Good overlap
- Consistent starts and stops

CHAPTER 31.

WEEK 4 LABS

Use a 100% argon gas when welding aluminum in these labs.

T-JOINT ALUMINUM

Setup

Materials required are two aluminum plates, each with 1/4″ thickness and measuring 1″ x 5″. You may use a spool gun or a push-pull gun for this lab.

Position required is 2F.

Work

Create a t-joint with 5/16″ fillet welds. The joint should have a minimum of three welds. Be aware of not wasting material!

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- Minimum of three (3) welds on the single joint

BEADS ON A TUBE

Setup

Materials required are a single 1/8″ thick aluminum round tube, 4″ long and with a 4″ or 5″ outer diameter. You may use a spool gun or a push-pull gun for this lab.

Positions required are 2G and 5G.

Work

On the tube, surfacing weld two layers in the 2G position and two layers in the 5G position.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut

- Complete penetration
- No porosity
- Beads must overlap at least halfway onto previous bead

CHAPTER 32.

WEEK 5 LABS

All of the labs for Week 5 use GMAW spray arc. Use a gas mixture of 90% argon and 10% carbon dioxide when welding with spray transfer in these labs.

Base metals must be clean of mill scales before attempting these welds.

BEADS ON PLATE 1G SPRAY TRANSFER

Setup

Materials required are a single 3/16″ to 3/8″ thick steel plate measuring 3″ by 6″.

Positions required are 1G and 2G.

Work

Weld two layers of surfacing beads on the plate in 1G position. On a separate location on the same plate, weld two layers of surfacing beads in 2G position.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- Beads must overlap at least halfway onto previous bead

T-JOINT 2F MULTI-PASS GMAW SPRAY

Setup

Materials required are your previously constructed x-block with 1/4″ thick steel plates and with overall dimensions of 2″ by 2″ by 18″.

Position required is 2F.

Work

Create a t-joint with 5/16″ fillet welds and multiple passes. This will be the final side of your x-block!

Acceptance Criteria

- Consistent weld
- No porosity

- No undercut
- No cracks
- Beads must overlap at least halfway onto previous bead

T-JOINT 2F 4″ TUBE TO PLATE GMAW SPRAY

Setup

Materials required are a single 1″ long steel round tube with a 4″ or 5″ outer diameter and at least 3/16″ thickness, and a single steel plate with thickness between 3/16″ to 1/2″ and dimensions that allow at least 1″ of visible edge around the tube.

Position required is 2F.

Work

Weld the open end of the tube to the plate with no more than four stops and starts.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- No porosity
- No more than four (4) stops and starts to complete the weld

T-JOINT 2F 2″ TUBE TO PLATE GMAW SPRAY

Setup

Materials required are a single 1″ long steel round tube with a 2″ outer diameter and at least 3/16″ thickness, and a single steel plate with thickness between 3/16″ to 1/2″ and dimensions that allow at least 1″ of visible edge around the tube.

Position required is 2F.

Work

Weld the open end of the tube to the plate with no more than four stops and starts.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- No porosity

- No more than four (4) stops and starts to complete the weld

CHAPTER 33.

WEEK 6 LABS

Both of these welds should be completed with gas-shielded welding and 0.045″ diameter E71T-1 wire.

STRINGER BEADS ALL POSITIONS FCAW

Setup

Materials required are a single 3/8″ thick steel plate measuring 3″ by 6″.
Positions required are 1G, 2G, 3G, and 4G.

Work

Using FCAW-G, weld 2 layers of surfacing beads on the plate. Each pair of layers should be completed in a different position.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- No undercut
- Complete penetration
- Half overlap over previous weld bead

ANGLE IRON X-BLOCK FCAW

Setup

Materials required are a single angle iron, 1/4″ thick, measuring 2″ by 2″ by 18″.
Positions allowed are 1F, 3F, and 4F.

Work

Using FCAW-G, weld multiple layers of stringer beads inside the x-block. Fill the block completely.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- Consistent overlap
- Complete penetration

CHAPTER 34.

WEEK 7 LAB

This lab should be completed with gas-shielded welding and 0.045″ diameter E71T-1 wire.

WABO FCAW

Setup

Materials required are a single WABO plate, 2″ thick. One side of the v groove is 90°, the other side is cut at 45°. The plate has a 1/4″ root opening with a 3/8″ backing bar.

Position required is 2F.

Work

Weld multiple layers of stringer beads to fill the WABO plate. Two 3/8″ coupons will be cut out and run through the bend test.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- Complete joint penetration
- Both coupons pass the bend test

CHAPTER 35.

WEEK 8 LAB

This lab should be completed with gas-shielded welding and 0.045″ diameter E71T-1 wire.

WABO FCAW

Setup

Materials required are a single WABO plate, 1″ wide. The plate has a 1/4″ root opening with a 3/8″ backing bar. Every student gets a single 8″ length of plate; the final object must measure 6″ long.

Positions allowed are 3G and 4G.

Work

Weld multiple layers of stringer beads to fill the WABO plate.

Acceptance Criteria

- Consistent weld
- Good tie-ins
- Complete joint penetration
- Your instructor **must see** your fit up, root pass, and cover pass on every part!

CHAPTER 36.

LAB TIPS: STEPS BEFORE WELDING

If you already know how to set up and use a wire feed welding machine, congratulations, this page is not for you!

If you are unfamiliar with wire feed welding, please read this before you start welding.

All of LWTech's wire feed setups use a power source with a separate wire feeder. The wire feeders are mounted to the side of the concrete booths, they are mounted upside down in that the power and read outs are facing down towards the ground. **Check to make sure your wire feeder is turned on.**

Find the power source associated with the booth you are going to be using. The power sources have a 100% Duty Cycle and can be run almost indefinitely, this means that the fans inside are always running and can be very loud. **Wear ear plugs!**

We have both digital and analog read outs on our power supplies. Both, have a large power on/off switch, and a dial to indicate which process you are doing. **Check to see if it's on GMAW or FCAW.** There should be an image on the dial to indicate the type of welding gun you're using.

All the leads should be already connected. **If the leads are not connected or you cannot find them, please find an instructor to help you.**

Double check that **the plastic screens are down** and you have **all your personal protective equipment**, or PPE, before you start welding.

CHAPTER 37.

LAB TIPS: GMAW SHORT CIRCUIT

SETTINGS

Acceptable ranges for welding GMAW short circuit:

- 16-22 volts
- 150 – 223 wire-speed

Example settings (notice how the numbers match?):

- 17 volts and 170 wire-speed
- 19 volts and 190 wire-speed
- 22 volts and 220 wire-speed

Use a gas mixture of 75% argon and 25% carbon dioxide for GMAW short circuit. For GMAW spray transfer, instead use a gas mixture of 90% argon and 10% carbon dioxide.

OTHER TIPS

- Take mill scale off the joint (both the front and back sides).
- Prop the joint up off the table so it doesn't stick.
- When welding verticle up, use lower settings with a slight triangle movement.

COMMON MISTAKES

1. Not cleaning your material: get your material clean from mill scale and do not weld on rusted material.
2. Voltage issues: too high creates a globular weld, too low often doesn't even melt the wire.
3. Wire feed speed issues: too high may not melt the wire, too low leads to single drops onto the plate rather than a continuous feed.
4. Electrical wire positioning: it is often recommended that the wire sticks out 3/4″ past the contact tip (not past the nozzle!) to the material.
5. Gas flow issues: too low creates porosity, too high wastes gas and may also create porosity.
6. Travel speed issues: too fast creates a too-narrow bead with peaks, too slow creates a super wide bead.
7. Gun angle: causes issues with shielding gas coverage if the push or drag angle is too much.

CHAPTER 38.

LAB TIPS: ALUMINUM

For safety purposes, remember that the welding machines will run hot; be aware of your surroundings.

When welding with aluminum, start with the following settings:

- 21 volts
- 220 wirespeed
- 30ish gas

Because aluminum will stay hot for longer than steel, you can't weld one side and then immediately do the other side. Instead, have a few pieces set up to work on at the same time, giving your welds time to cool before returning to a given piece.

Also be wary of bird nesting as you weld; having to stop to untangle your wire will drag everything to a halt.

HOW TO ASSESS A FILLET WELD

Assessing the quality of a fillet weld is crucial to ensure its structural integrity and suitability for the intended application. Fillet welds are commonly used to join two pieces of metal at an angle, forming a triangular cross-section between the two pieces. Here's how to assess a fillet weld:

VISUAL INSPECTION

- Begin by visually inspecting the fillet weld. Check for visible defects such as cracks, incomplete fusion, undercut, overlap, porosity (voids), and excessive convexity or concavity.
- Examine the appearance of the weld surface. A good fillet weld should be smooth and consistent, without irregularities or rough spots.

MEASUREMENT

- Use a measuring tool, such as a fillet weld gauge or a simple ruler, to measure the leg lengths and throat depth of the fillet weld.
- *Leg length* refers to the perpendicular distance from the root of the joint to the toe of the weld. It should meet the design specifications to ensure proper strength and load-bearing capacity.
- *Throat depth* is the shortest distance from the root of the weld to the face of the weld. It provides an indication of the weld's effective cross-sectional area.

VISUAL CRITERIA

- Refer to applicable industry standards, codes, and project specifications to determine the acceptable limits for defects, dimensions, and appearance of fillet welds.
- Compare the observed weld with the criteria outlined in the standards to determine if the weld meets the required standards for quality and safety.

TACTILE INSPECTION

- Run your fingers over the weld surface to detect any irregularities or roughness that might not be immediately visible.
- Ensure that the weld is smooth and does not have any sharp edges or protrusions that could cause stress concentrations.

FILLET WELD GAUGE

- A *fillet weld gauge* is a specialized tool that helps assess the size and quality of a fillet weld. It can measure leg lengths, throat depth, and angles.
- The gauge should match the specified dimensions of the weld to ensure compliance with

design requirements.

MATH IN WELDING

Math is an essential part of the welding process. Welders use math to make precise measurements, fabricate projects, calculate correct settings based on variables, give accurate and fair estimates, and use logic to speed up fabrication processes.

MEASUREMENT SYSTEMS

The US customary system (e.g. inch, foot, yard, mile) is the most commonly used measurement system in the US. Most weld shops use this system of units. The most basic unit of distance is an inch, and it builds from there: 12 inches is 1 foot, 3 feet is 1 yard, and 1760 yards is 1 mile. Most jobs are done using inches and/or feet. Inches can be broken up into fractions (typically multiples of 8). The standard notation (e.g. 6′-2″) follows several rules:

- If both feet and inches are noted, feet are noted first. (Sometimes only inches are used.)
- If both feet and inches are noted, they are separated with a dash.
- Feet are marked with an apostrophe (e.g. 6′) and inches with quotation marks (e.g. 13″).

The international system of units, also known as the SI system or the metric system, is recognized by all countries and has been standardized across the world. The most basic unit of distance is a millimeter, and subsequent units are multiples of 10: 10 millimeters is 1 centimeter, 10 centimeters is 1 meter. This is a much simpler system than the US customary system because it is based on decimals.

LINEAR MEASUREMENTS

A *linear measurement* is a measurement taken in a straight line, usually with tape measures or rulers. It is important to be as accurate as possible when measuring and to check your measurement twice. If you are measuring from a blueprint, verify that the number you are reading is correct before cutting out your parts.

A *tolerance* (an acceptable range of deviation) may allow for a final product that is over or under the ideal measurement. Tolerances are usually given by a +/- or ± symbol, with the combination of the plus and minus signs demonstrating that you can go over or under the measurement given, but it is important to stay within that tolerance.

CONVERTING UNITS

The most common conversions welders may have to do are below. Calculators are encouraged if you need them! It’s better to be accurate than to be showy.

- To convert from feet to inches, multiply by 12.
- To convert from inches to feet, divide by 12.
- To convert from inches to millimeters, multiply by 25.4.

- To convert from millimeters to inches, divide by 25.4.

VISUAL INSPECTION CRITERIA

The following criteria are based on industry standards and accepted codes, but are not intended to be understood as code themselves. The following are intended to aid the student and instructor in evaluating lab assignments and assigning grades to those assignments. Specific points are not assigned for each criterion; rather, the lab coupons are compared to these criteria as a whole.

VISUAL ACCEPTANCE CRITERIA FOR THERMAL CUTTING

Aspect	Unacceptable	Acceptable	Outstanding
Square to Top	Majority of cut alternates between acute and obtuse angles rather than prescribed angle	Majority of cut follows prescribed angle	No easily detectable deviation from prescribed angle
Smoothness of Kerf	Cut is jagged, kerf lines indicate improper travel speed, or excessive dross	Great majority of cut is smooth, kerf lines indicate proper travel speed, little dross that is easily removed	No jagged edges on cut, texture is uniformly smooth with kerf lines less than 1/64" in depth
Follows Layout Lines	Cut generally deviates from layout lines	Great majority of cut follows layout lines	Any deviations from layout are difficult to detect
Top Edge of Cut	Top edge is rounded, with melted appearance or bubbled up dross	Majority of cut has "crisp" top edge	Entire top edge of cut has "crisp" top edge

VISUAL ACCEPTANCE CRITERIA FOR FILLET WELDS

Aspect	Unacceptable	Acceptable	Outstanding
Defects/ Discontinuities	More than 5% of weld shows any of the following: Lack of fusion, overlap, slag inclusion, undercut, crater cracks, underfill, porosity, arc strikes outside weld joint	No overlap, cracks, slag inclusions, or underfill. No more than 5% of weld shows undercut exceeding 1/32" in depth, minor porosity, no more than 1/8" face reinforcement	No visible defects, no easily detectable or measurable discontinuities
Leg Length	Excessive difference in leg lengths, alternating leg lengths resulting in face of weld having a "twisting" appearance	Leg length nearly equal, consistent for length of weld. Face of weld is in "plane" for length of weld	Leg length is equal for length of weld
Throat*	Degree of concavity or convexity is visibly greater than 1/8"	Degree of concavity or convexity is visibly between 1/16" and 1/8"	Degree of concavity or convexity is visibly less than 1/16". Thickness of throat is uniform entire length of weld
Bead Width	Width varies greatly from one end of bead to other. SMAW Bead exceeds width of 2 electrodes, GMAW/FCAW bead exceeds 10 wire diameters in width	Majority of weld bead is consistent in width, SMAW Bead does not exceed width of 2 electrodes, GMAW/FCAW bead does not exceed 10 wire diameters in width	Entire weld bead is consistent in width, SMAW Bead does not exceed width of 2 electrodes, GMAW/FCAW bead does not exceed 10 wire diameters in width
Ripples	Narrow "V" shape, too hot. Wide "C", too cold, slow	Much of weld bead shows consistent ripples, "C" shapes evenly spaced	Entire weld bead shows consistent ripples, "C" shapes evenly spaced
Multi-Pass Weld Tie-In	Weld beads show distinct separation between each other, crevices between crowns of weld beads	Weld beads overlap each other by at least 25%, minimal lows between crowns	Weld beads overlap each other by 50%, toe of each weld bead lies at center of previous bead. Surface of the weldment is smooth

* Note: Throat is measured from the hypotenuse of toes to the root.

VISUAL ACCEPTANCE CRITERIA FOR GROOVE WELDS

Aspect	Unacceptable	Acceptable	Outstanding
Defects/ Discontinuities	More than 5% of weld shows any of the following: Lack of fusion, overlap, slag inclusion, undercut, crater cracks, underfill, porosity, arc strikes outside weld joint	No overlap, cracks, slag inclusions, or underfill. No more than 5% of weld shows undercut exceeding 1/32" in depth, minor porosity, no more than 1/8" face reinforcement	No visible defects, no easily detectable or measurable discontinuities
Throat*	Degree of concavity or convexity is visibly greater than 1/8"	No concavity or underfill. convexity is visibly between 1/16" and 1/8"	No concavity or underfill. convexity is visibly between 1/16" and 1/8" Thickness of throat is uniform entire length of weld/joint is completely filled
Bead Width	Width varies greatly from one end of bead to other. SMAW Bead exceeds width of 2 electrodes, GMAW/FCAW bead exceeds 10 wire diameters in width	Majority of weld bead is consistent in width, SMAW Bead does not exceed width of 2 electrodes, GMAW/FCAW bead does not exceed 10 wire diameters in width	Entire weld bead is consistent in width, SMAW Bead does not exceed width of 2 electrodes, GMAW/FCAW bead does not exceed 10 wire diameters in width
Ripples	Narrow "V" shape, too hot. Wide "C", too cold, slow	Much of weld bead shows consistent ripples, "C" shapes evenly spaced	Entire weld bead shows consistent ripples, "C" shapes evenly spaced
Multi-Pass Weld Tie-In	Weld beads show distinct separation between each other, crevices between crowns of weld beads	Weld beads overlap each other by at least 25%, minimal lows between crowns	Weld beads overlap each other by 50%, toe of each weld bead lies at center of previous bead. Surface of weldment is smooth

* Note: Throat is measured from the hypotenuse of toes to the root.