RQF LEVEL 5

MATPV501

MANUFACTURING TECHNOLOGY

Pipes and Pressure Vessels Welding

TRAINEE'S MANUAL

October, 2024

RTB | RWANDA TVET BOARD

PIPES AND PRESSURE VESSELS WELDING

KOICA Korea International Cooperation Agency

TQUM TVET Quality Management Project

2024

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TABLE OF CONTENT

ACRONYMS

AC: Alternating Current

API: Application Programming Interface

ASME: American Society of Mechanical Engineers

CBT/A: Competency-Based Training and Assessment

CC: Constant current

CFH: Cubic Feet per Hour

CNC: Computer Numerical Control

CO2: Carbon Dioxide

DC: Direct Current

DCEN: Direct Current Electrode Negative

DCEP: Direct Current Electrode Positive

DPT: Dye Penetrant Testing

E.R: Electrode Rod

FCAW: Flux core arc welding

GMAW: Gas Metal Arc Welding

GTAW: Gas Tungsten Arc Welding

H.F: High Frequency

HAZ: Heat-Affected Zones

I.D: Inner Diameter

IPM: Inches Per Minute

IR: Infra-Red

JHA: Job Hazard Analysis

JSA: Job Safety Analysis

LPM: Litre Per Minute

MAG: Metal Active Gas

MIG: Metal Inert Gas

NDT: Non-Destructive Testing

O.D: Outer Diameter

PPE: Personal protective equipment

PVC: Polyvinyl Chloride

PWHT: Post-weld Heat Treatment

RT: Radiographic Testing

RTB: Rwanda TVET Board

SMA: Shape Memory Alloys

TIG: Tungsten Inert Gas

TQUM Project: TVET Quality Management Project

TVET: Technical and Vocational Education and Training

UT: Ultrasonic Testing

UV: Ultra-Violet

WFS: Wire Feed Speed

WPS: Welding Procedure Specificati

INTRODUCTION

This trainee's manual includes all the knowledge and skills required in manufacturing technology specifically for the module of **"Pipes and Pressure Vessels Welding ".** trainees enrolled in this module will engage in practical activities designed to develop and enhance their competencies. The development of this training manual followed the Competency-Based Training and Assessment (CBT/A) approach, offering ample practical opportunities that mirror real-life situations.

The trainee's manual is organized into Learning Outcomes, which is broken down into indicative content that includes both theoretical and practical activities. It provides detailed information on the key competencies required for each learning outcome, along with the objectives to be achieved.

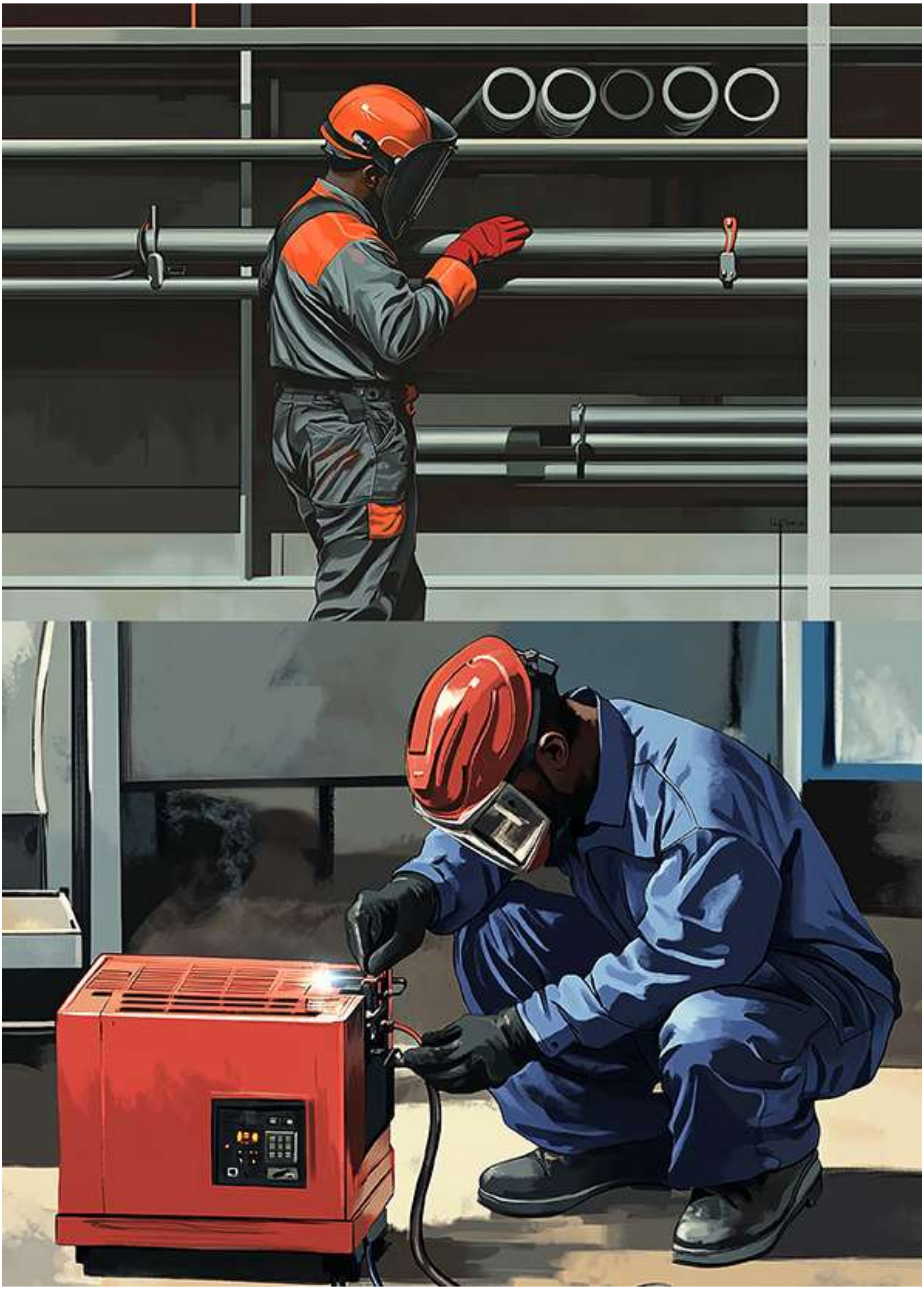
As a trainee, you will start by addressing questions related to the activities, which are designed to foster critical thinking and guide you towards practical applications in the labour market. The manual also provides essential information, including learning hours, required materials, and key tasks to complete throughout the learning process.

All activities included in this training manual are designed to facilitate both individual and group work. After completing the activities, you will conduct a formative assessment, referred to as the end learning outcome assessment. Ensure that you thoroughly review the key readings and the 'Points to Remember' section.

MODULE CODE AND TITLE: MATPV501 PIPES AND PRESSURE VESSELS WELDING

Learning Outcome 1: Organize the workplace.
Learning Outcome 2: Prepare the work piece.
Learning Outcome 3: Assemble pipes and Pressure vessels.

Learning Outcome 1: Organize the Workplace



Indicative contents
1.1 Introduction to pipes and pressure vessels welding **1.2 Preparing workplace** **1.3 Arranging materials, tools and equipment used for pipes and pressure vessel welding** **1.4 Setting MIG/MAG, TIG and FCAW equipment**

Key Competencies for Learning Outcome 1: Organize the workplace

Knowledge	Skills	Attitudes
● Description of pipe and pressure vessels welding ● Description of job hazards found in pipes and pressure vessels welding ● Description of materials, tools and equipment used in pipes and pressure vessels welding. ● Identification of factors for selecting materials, tools and equipment used in pipes and pressure vessels welding. ● Description of MIG/MAG, FCAW and TIG machine parameters	● Applying 5S at workplace ● Selecting materials, tools and equipment ● Applying handling techniques ● Connecting welding machine component ● Adjusting welding machine parameters ● Testing welding machine functionality	● Being attentive while applying 5S at workplace ● Being attentive while applying handling techniques. ● Being careful while connecting welding machine component ● Having precision while adjusting welding machine parameters ● Being self-confident when testing a welding machine functionality.

Duration: 20 hrs

Learning outcome 1 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Describe properly pipes and pressure vessels welding in manufacturing technology
2. Analyse effectively the job hazards at workplace as required in Pipes and Pressure Vessels welding
3. Apply appropriately 5S at workplace as required in Pipes and Pressure Vessels welding
4. Describe properly materials, tools and equipment used in Pipes and Pressure Vessels welding
5. Select correctly materials, tools and equipment required in Pipes and Pressure Vessels welding process
6. Apply properly handling techniques used in Pipes and Pressure Vessels welding
7. Describe clearly the welding machine parameters as required in Pipes and Pressure Vessels welding
8. Test correctly the MIG/MAG, TIG and FCAW equipment used in Pipes and Pressure Vessels welding

Resources

Equipment	Tools	Materials
• TIG machine kit • Shielding Gas cylinder • Oxyacetylene kit • Air compressor • Painting gun • Pipe cutting machine	• Micrometres • Tape measures • Protractors • Pencils • Scribes • Punch • Marking gauges	• MIG wire • Shielding gas • Filler rod • FCAW wire • Paint • Thinner • Discs

• Shearing machine • Laser cutting machine • Plasma cutting machine • Angle grinder • Cut off machine • Bending machine • Rolling machine • Fume extractor • Drilling machine • PPEs (Welding gloves, Welding helmet, Safety boot, Over all, Safety glass and Face shield)	• Vices • Hammers • Screwdrivers • Pliers • Wrenches • Saws • Drills bit • Shears • Brush • Rollers.	• Sanding papers • Oil • Fuel • Masking tape

Indicative content 1.1: Introduction to Pipes and Pressure Vessels Welding

Duration: 5 hrs

Theoretical Activity 1.1.1: Description of pipes and pressure vessels welding

Tasks:

1: Answer the following questions:

i. What do you understand by the following terms used pipes and pressure vessels welding?

a) Pipe
b) Pressure vessel
c) Shielding Gas

ii. What do you understand by the following welding methods?

a. MIG/MAG
b. FCAW
c. TIG

iii. What could be the areas of applications of pipes and pressure vessels welding?

iv. what should be the advantages and disadvantages of pipes and pressure vessels welding?

2: Write the answers provided on flipchart/papers.

3: Present your findings to your classmates and trainer.

4: For more clarification, read the key readings 1.1.1. and ask questions where necessary.

Key readings 1.1.1.: Description of pipes and pressure vessels welding

- **Definition of key terms:**
  - ✓ **Pipe:** Is a long hollow cylindrical tube made from various metals or metal alloys, designed to transport fluids, gases, or other materials and for structural purposes.
  - ✓ **Pressure vessel:** Is sealed containers designed to hold liquids, gases, or vapours at pressures significantly different from the surrounding environment.

✓ **Shielding Gas:** Is an inert or semi-inert gas used in welding processes, such as MIG (Metal Inert Gas) or TIG (Tungsten Inert Gas) welding, to protect the molten weld pool from atmospheric contamination.

- **Pipes and pressure vessels welding methods**

✓ **MIG/MAG**

MIG/MAG welding, also known as Gas Metal Arc Welding (GMAW)**,** is a process that uses a continuous solid wire electrode, fed through a welding gun/torch, to create an electric arc between the electrode and the work piece. This arc melts the electrode and base material, forming a weld.

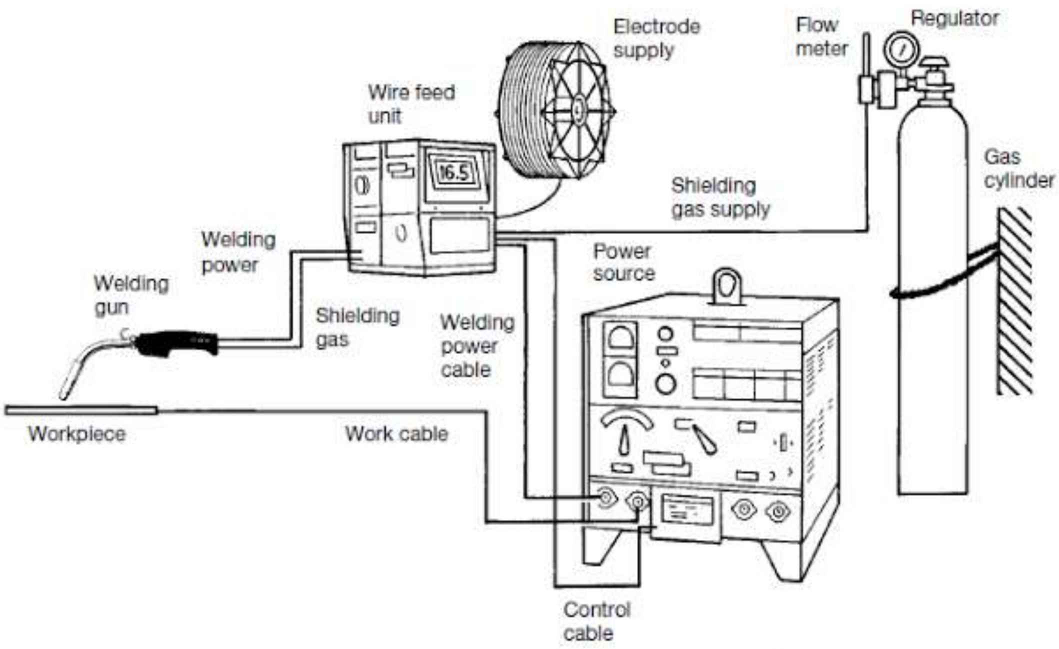


Figure 1: MIG/MAG set-up

- **MIG (Metal Inert Gas)** welding uses an inert gas (such as argon or helium) as a shielding gas to protect the weld pool from atmospheric contamination. It is typically used for non-ferrous metals like aluminium and copper.
- **MAG (Metal Active Gas)** welding uses an active gas (such as carbon dioxide or a CO_2 mix) as the shielding gas, which can react with the molten metal to enhance the welding process. It is commonly used for ferrous metals like steel.

1. **Advantages MIG/MAG**

- **High speed and efficiency**: MIG welding allows for continuous welding with a high deposition rate, making it a fast process.
- **Clean welds**: The inert gas shield prevents contamination and oxidation, leading to clean, high-quality welds with minimal spatter.
- **Ease of use**: The process is relatively easy to learn and use, making it accessible for both beginners and experienced welders.
- **Minimal Post-Weld Clean-up**: The inert gas shield reduces the amount of slag and spatter, resulting in less post-weld cleaning.

2. **Disadvantages/ MIG/MAG**

- **Limited to thin materials**: MIG welding may not be ideal for very thick materials compared to other welding methods like flux-cored arc welding (FCAW).
- **Sensitivity to wind and drafts**: The inert gas shield can be disrupted by wind or drafts, affecting weld quality if used outdoors without proper protection.
- **Equipment cost**: MIG welding equipment can be relatively expensive compared to some other welding methods.

✓ **FCAW**

FCAW (Flux-Cored Arc Welding): Is a welding process that uses a continuously fed tubular electrode filled with flux to create a weld. The process is similar to MIG (Metal Inert Gas) welding, but instead of a solid wire, FCAW employs a flux-cored wire, which provides additional protection and alloying elements.

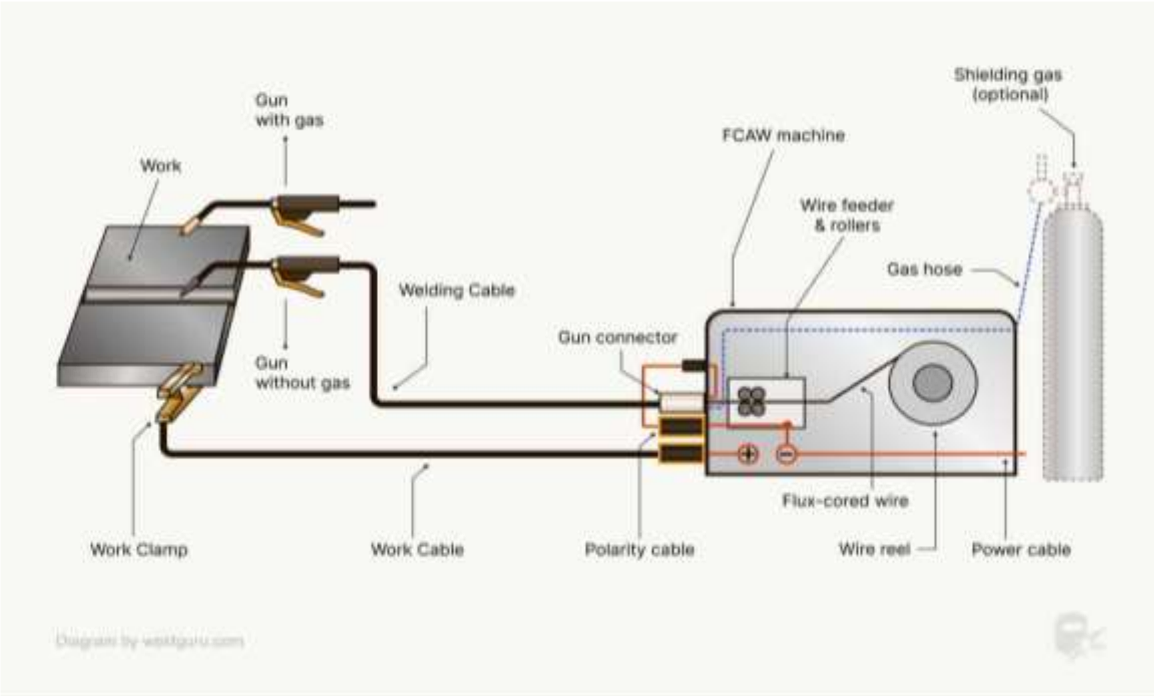


Figure 2: FCAW set-up

Flux-cored electrode: The electrode is a hollow wire filled with flux, which melts to form a protective shield around the weld pool, reducing the need for external shielding gases.

Shielding: The flux inside the core produces a gas shield when heated, protecting the weld pool from atmospheric contamination. This makes FCAW suitable for outdoor welding or in environments where wind could disrupt gas shielding.

✓ **TIG**

TIG (Tungsten Inert Gas) welding, also known as Gas Tungsten Arc Welding (GTAW)**,** is a welding process that uses a non-consumable tungsten electrode to produce the weld. The process relies on an inert gas, usually argon or helium, to shield the weld area from atmospheric contamination.

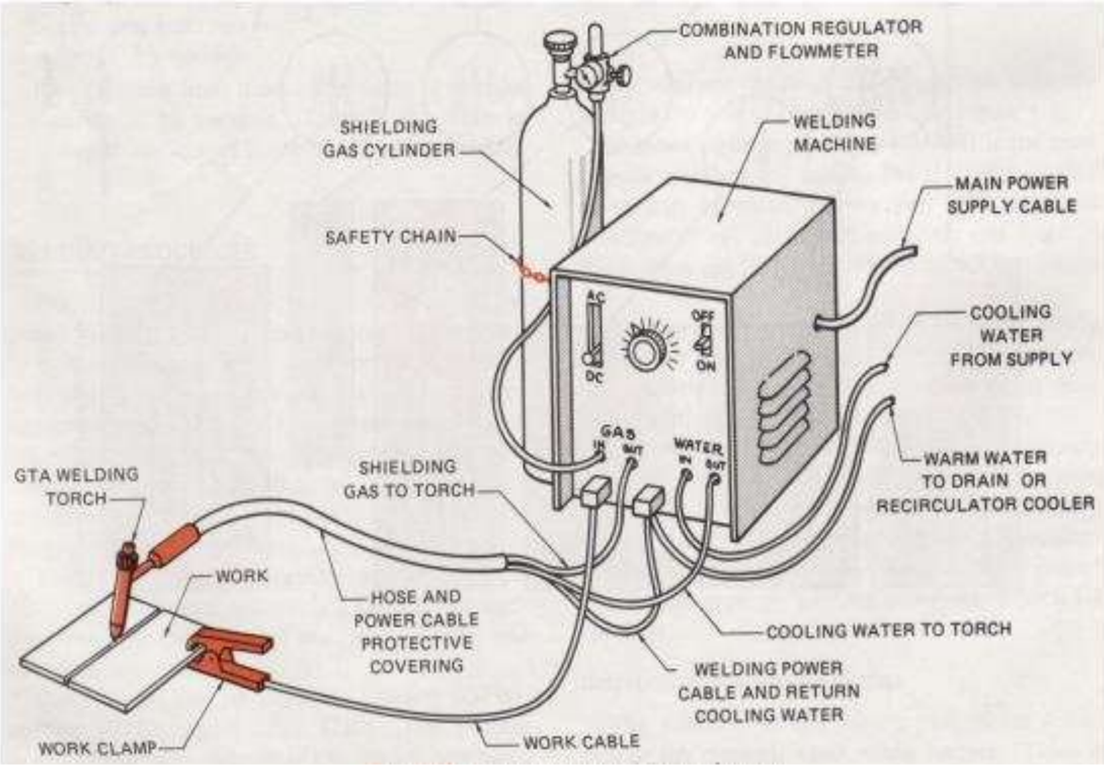
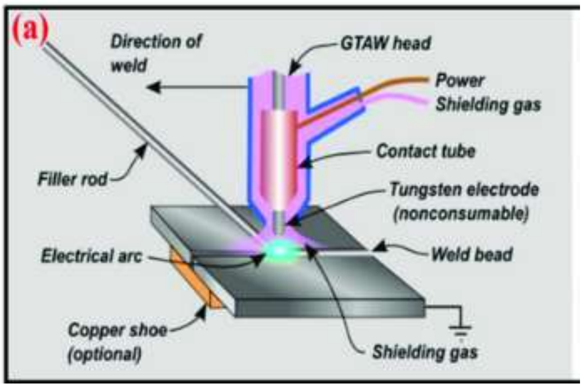


Figure 3: TIG set-up

Tungsten electrode: A non-consumable tungsten electrode creates the electric arc necessary for welding. The electrode remains intact throughout the welding process and does not melt or become part of the weld.
Shielding gas: An inert gas, such as argon or helium, is used to protect the weld pool and the tungsten electrode from atmospheric gases like oxygen and nitrogen. This prevents contamination and oxidation of the weld.
Filler material: While the tungsten electrode does not melt, a separate filler material may be used to add to the weld pool if needed. The filler is typically fed manually by the welder.



- **Application of pipes and pressure vessels welding**
- ✓ **Applications of pipe welding**

- **Pipeline construction**: Welding is used to join sections of pipelines that transport oil, natural gas, and other fluids over long distances.
- **Water supply**: Welded pipes are used in municipal water supply systems to transport water from treatment plants to consumers.
- **Sewage systems**: Pipe welding is employed in the construction of sewer systems to handle wastewater and sewage.
- **Chemical transport**: Pipes are welded to transport chemicals and other hazardous materials safely within plants.
- **Power Plant piping**: Welded pipes are used in steam and gas turbines, as well as in cooling systems to handle high-pressure steam and other fluids.
- **Bridges and structures**: Pipes are welded into structural components for various construction projects.

✓ **Applications of pressure vessel welding**

- **Heat exchangers**: Welded pressure vessels are used to transfer heat between fluids in various industrial processes.
- **Storage tanks**: Welded pressure vessels are used for storing crude oil, natural gas, and refined products.
- **Boilers**: Pressure vessels are integral parts of boilers in power plants, where they handle high-pressure steam.
- **Steam generators**: Welded pressure vessels are used to generate steam for power generation and heating.

- **Advantages and disadvantages of pipes and pressure vessels welding**

✓ **Advantages of welding pipes and pressure vessels**

- **Strength and durability**: Welding provides a strong and durable joint that can withstand high pressure and stress, making it suitable for pressure vessels and pipelines that must handle significant internal forces.
- **Leak proof**: Properly executed welds ensure a leak-proof seal, which is crucial for maintaining the integrity and safety of pressure vessels and pipelines.
- **Versatility**: Welding can be applied to a variety of metals and alloys used in pipes and pressure vessels, including steel, stainless steel, and exotic alloys.
- **Cost-effective**: Welding is often more cost-effective than other methods of joining metals, such as riveting or bolting, due to the reduction in labor and materials required.

- **Uniformity**: Welding produces a uniform joint with consistent quality and strength, which is important for the reliable operation of pressure vessels and pipelines.
- **Flexibility in design**: Welding allows for complex geometries and custom designs, accommodating a wide range of shapes and sizes in pressure vessels and piping systems.

✓ **Disadvantages of welding pipes and pressure vessels**

- **Skill and expertise required**: Welding requires a high level of skill and expertise to ensure the quality and integrity of the welds. Poor welding can lead to defects and failures.
- **Inspection and testing**: Welds often require thorough inspection and testing (such as radiographic or ultrasonic testing) to ensure they meet safety and quality standards, which can increase project costs and time.
- **Heat-affected zone**: The heat generated during welding can alter the properties of the surrounding material, creating a heat-affected zone (HAZ) that may be more susceptible to stress and corrosion.
- **Welding defects**: Common welding defects such as porosity, cracks, and incomplete fusion can compromise the strength and safety of the welds. Addressing these defects may require rework or repairs.
- **Thermal distortion**: The heat from welding can cause thermal distortion and warping, which may affect the dimensions and alignment of pipes and pressure vessels.
- **Preparation and cleanliness**: Proper surface preparation and cleanliness are crucial for achieving high-quality welds. Contaminants like rust, oil, or dirt can lead to weld defects and reduced joint strength.

Points to Remember

- Each welding method has specific advantages, and the selection of the right process depends on factors such as the materials being welded, joint configuration, service conditions, weld strength, and environmental conditions
- Welding of pipes and pressure vessels offers numerous advantages, including strong, reliable joints, versatility in materials, and cost-effectiveness for large-scale projects.
- Careful planning, proper selection of welding processes, and attention to detail are essential to ensure the successful fabrication and long-term integrity of welded pipes and pressure vessels.

Application of learning 1.1.

In your school manufacturing workshop, there is a welding technician who is assembling mild steel water tank by welding. You are requested to observe the process and generate a study report on:

1. Pipes and pressure vessels welding terminologies
2. Welding methods used in pipes and pressure vessels welding
3. Advantages and disadvantages of pipes and pressure vessels welding
4. Application areas of pipes and pressure vessels welding

Indicative content 1.2: Preparing Workplace

Duration: 5 hrs

Theoretical Activity 1.2.1: Description job hazards

Tasks:

1: Answer the following questions:

i. What could be the types of hazards in pipes and pressure vessels welding?

ii. What should be the hazards control techniques in pipes and pressure vessels welding?

2: Write the answer provided on flipchart/papers.

3: Present your findings to your classmates and trainer.

4: For more clarification, read the key readings 1.2.1. and ask questions where necessary.

Key readings 1.2.1.: Description job hazards

- **Analysing job hazard**

Job Hazard Analysis (JHA), also known as Job Safety Analysis (JSA), is a process used to identify and mitigate potential hazards associated with specific job tasks or activities in the workplace. The goal is to reduce risks by analysing tasks, understanding the hazards involved, and implementing measures to control or eliminate those hazards.

✓ **Key elements of job hazards analysis**

i. **Identify the job or task**

Select a specific job or task for analysis, particularly one that has a high risk of injury, is performed frequently, or has been associated with past accidents or near misses.

ii. **Break down the job into steps**

List all the steps involved in completing the job, from start to finish. This breakdown should include each action a worker takes to accomplish the task.

iii. **Identify hazards in each step**

For each step, determine what hazards are present. These could be physical hazards (like slips, trips, and falls), chemical hazards (like exposure to harmful substances), or ergonomic hazards (like repetitive motion).

iv. **Determine control measures**

For each identified hazard, determine appropriate controls to minimize or eliminate the risk. These controls fall under the hierarchy of controls (elimination, substitution, engineering controls, administrative controls, and personal protective equipment).

v. **Implement and review**:

Implement the identified control measures in the workplace. It's essential to review the JHA periodically or whenever there are changes in the process, equipment, or personnel to ensure that the hazards are still controlled effectively.

- **Hazards related to pipes and pressure vessels welding**

  ✓ **Explosion and fire hazards**

- Welding pipes and vessels containing or that have previously contained flammable substances (like gas or oil) can lead to explosions if not properly cleaned or purged.
- Welding produces sparks, which can ignite flammable materials nearby, causing fires.

  ✓ **Toxic fumes and gases**

- Welding can produce toxic fumes (like carbon monoxide, ozone, and nitrogen oxides) and other hazardous chemicals depending on the material being welded (such as chromium, lead, or cadmium).
- Confined spaces inside pressure vessels can limit ventilation, increasing the concentration of harmful gases and posing a serious health risk through inhalation.

  ✓ **Electrical hazards**

- **Electric shock**: Arc welding involves high-voltage equipment, which can lead to electric shock if proper grounding, insulation, and PPE are not used.
- **Faulty wiring**: Damaged or improperly maintained welding equipment can increase the risk of electric shock or fire.

  ✓ **Mechanical hazards**

- Pipes and pressure vessels can be large and heavy, creating risks of falling objects, pinching, or crushing during handling or positioning.
- Improperly supported or anchored materials can shift or fall during welding, posing a risk of injury.

  ✓ **Radiation exposure**

- **Arc welding** emits ultraviolet (UV), infrared (IR), and visible light radiation, which can cause burns to the skin and eyes.
- Prolonged or unprotected exposure can lead to skin damage and long-term health issues such as cataracts.

✓ **Noise hazards**

- Welding processes, particularly those involving grinding or cutting, can generate high levels of noise, leading to hearing damage or loss over time without proper hearing protection.

✓ **Confined space hazards**

- Welding inside vessels or enclosed areas can increase the risks of asphyxiation (due to lack of oxygen) or toxic gas build-up.
- Limited escape routes can make rescue efforts difficult in case of emergencies.

- **Controlling hazard in pipe and pressure welding**

Controlling hazards in the workplace, especially in activities like welding, is essential to ensuring worker safety and preventing accidents. Various techniques are used to manage and reduce risks, generally falling into the hierarchy of controls.

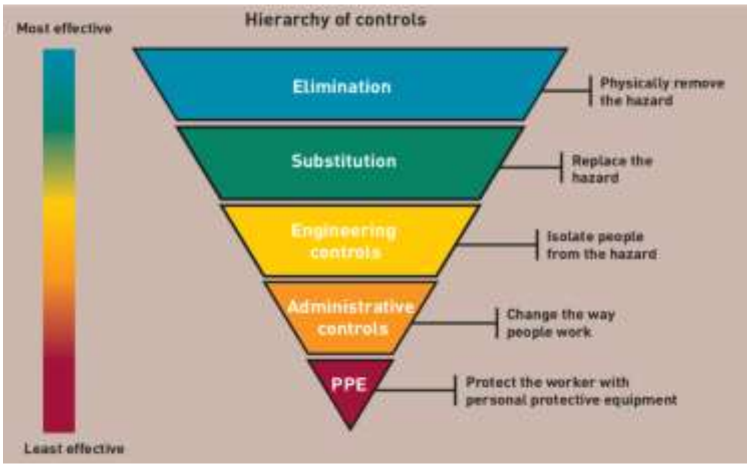


Figure 4: Hierarchy of control

✓ **Elimination**

This is the most effective method of hazard control, where the hazard is physically removed or eliminated from the workplace.

Example:

- Instead of welding a pipe that contains hazardous materials, workers may clean, drain, and purge the pipe to eliminate the risk of fire or explosion.

✓ **Substitution**

Replacing a hazardous substance, material, or process with a safer one. Example**:**

- Use a less toxic welding gas or replace a flammable material with a non-flammable one during operations.

✓ **Engineering Controls**

These controls focus on isolating people from the hazard by modifying equipment or physical environments.

Examples:

- **Ventilation systems** to remove toxic fumes or gases generated during welding.
- **Automatic shutoff valves** in pressure vessels to release pressure before welding begins.
- **Guards or shields** around welding areas to protect other workers from sparks, radiation, or spatter.

✓ **Administrative Controls**

These controls involve changes to work policies, procedures, training, or scheduling to minimize exposure to hazards.

Examples:

- **Safety training**: Educating workers about proper welding techniques, hazard recognition, and emergency procedures.
- **Job rotation**: Reducing the amount of time an individual is exposed to a hazardous task by rotating employees to different positions.
- **Work permits**: Using hot work or confined space entry permits to ensure that all safety measures are in place before welding begins.
- **Signage and warning systems**: Posting signs in areas with specific hazards and using alarms or signals to warn workers.

✓ **Personal Protective Equipment (PPE)**

PPE provides a physical barrier between the worker and the hazard. It is considered the last line of defence when hazards cannot be completely eliminated.

Examples:

- **Welding helmets** with proper lens shade to protect the eyes from UV and infrared radiation.
- **Flame-resistant clothing**, gloves, and boots to protect against heat, sparks, and molten metal.
- **Respirators** to protect against inhaling toxic fumes, especially in confined or poorly ventilated spaces.
- **Hearing protection** such as earplugs or earmuffs in noisy environments.

✓ **Isolation**

This involves physically separating the hazard from workers, either by distance or barriers.

Examples:

- **Enclosures** around welding operations to prevent exposure to other workers.
- **Remote-controlled systems** for hazardous tasks, allowing workers to operate machinery or perform welding from a safe distance.

Practical Activity 1.2.2: Applying 5S in preparing workplace for pipes and pressure vessels welding

Task:

You are requested to go in manufacturing workshop and prepare workplace by applying 5S as required for pipes and pressure vessels welding.

1: Apply safety precautions.

2: Apply 5S as required for workplace preparation in pipes and pressure vessels welding

3: Present your work to the trainer and whole class.

4: Read key reading 1.2.2 and ask clarification where necessary.

5: Perform the task provided in application of learning 1.2.

Key readings 1.2.2: Applying 5S in preparing workplace of pipes and pressure vessels welding

- **5S principle**

The **5S principle** is a workplace organization method developed in Japan, aimed at improving efficiency, safety, and cleanliness. It focuses on creating a structured, organized, and well-maintained work environment, which helps reduce waste, improve productivity, and enhance safety. The five S's stand for **Sort, Set in Order, Shine, Standardize, and Sustain**.

Figure 5: 5S

✓ **Sort**

- Eliminate unnecessary items from the workplace, keeping only what is essential.
- Sort through all tools, materials, and equipment, and remove anything that is not needed for the current job or process. This reduces clutter, frees up space, and makes the workspace more efficient.

✓ **Set in order**

- Organize all necessary items so that they are easily accessible and located in logical places.
- Arrange tools, materials, and equipment in a way that promotes easy access and efficient workflow. Everything should have a designated place, and tools should be returned to their assigned location after use.

✓ **Shine**

- Clean the work area regularly to ensure it remains free of debris, dirt, and clutter.
- This step emphasizes cleanliness and the importance of keeping workspaces in good condition. Regular cleaning prevents hazards, promotes safety, and

enhances equipment lifespan.

- ✓ **Standardize (Seiketsu)**
  - Create consistent processes and practices to maintain the organization, cleanliness, and efficiency established by the first three S's.
  - Develop standard operating procedures (SOPs) to ensure that sorting, organizing, and cleaning become regular practices, not one-time events. These standards should be applied uniformly across all areas.

- ✓ **Sustain (Shitsuke)**
  - Maintain discipline and make 5S a continuous process by developing habits and training workers to adhere to the system.
  - Sustainment involves ongoing training, audits, and reinforcement of the 5S principles. It requires everyone's commitment to maintain the practices and make 5S part of the workplace culture.

Figure 6: Unarranged tools (left) and arranged tools (right)

Points to Remember

- Proper PPE, equipment maintenance, and adherence to safety protocols can mitigate the pipe and pressure vessels welding hazards.
- When 5S are applied effectively, workers spend less time searching for tools or materials because everything is organized.
- Remember that if workplace is organized and cleaned properly, processes can flow smoothly, reducing downtime or delays

Application of learning 1.2.

There is a welding activity in your school's manufacturing workshop of assembling a 1000m³ mild steel cylindrical tanks, but the workplace is not properly prepared. You are asked to organize the workplace.

Indicative content 1.3: Arranging Materials, Tools and Equipment Used for Pipes and Pressure Vessel Welding

Duration: 5 hrs

Theoretical Activity 1.3.1: Description of materials, tools and equipment used in pipes and pressure vessels welding

Tasks:

1: Answer the following questions:

i. What could be the types materials used in pipes and pressure vessels welding?

ii. What could be the types of tools used in pipes and pressure vessels welding?

iii. What could be the types equipment used in pipes and pressure vessels welding?

iv. What should be the selection factors of materials, tools and equipment as required in p ipes and pressure vessels welding?

2: Write the answer on flipchart/papers.

3: Present your findings to your classmates and trainer.

4: For more clarification, read the key readings 1.3.1. and ask questions where necessary.

Key readings 1.3.1.: Description of materials, tools and equipment used in pipes and pressure vessels welding

- **Materials**
  - ✓ **Pipes**

A pipe is a hollow, cylindrical tube used to transport fluids (liquids or gases) from one location to another. Pipes are essential components in many industries, including plumbing, oil and gas, chemical processing, power generation, and more.

- **Types of pipes**
- **Galvanized pipe:** Refers to a steel pipe that has been coated with a layer of zinc to protect it from corrosion. This process is known as galvanization**,** and it involves immersing the steel pipe into a molten zinc bath or applying zinc coatings through other methods such as electroplating or hot-dip galvanizing.

Figure 7: Galvanized pipe

- **Characteristics of galvanized pipe**
- **Corrosion resistance:** The primary purpose of galvanization is to protect the underlying steel from corrosion and rust.
- **Longevity:** Galvanized pipes are known for their durability and long service life.
- **Fire resistance:** Galvanized pipes have a degree of fire resistance,
- **High strength:** Galvanized steel pipes maintain the mechanical strength of regular steel pipes. They are strong and can withstand pressure and external forces, making them suitable for structural applications.
- **Stainless steel:** Stainless steel is a versatile material comprised of a steel alloy and a small percentage of chromium the addition of chromium adds to the material's corrosion resistance; Stainless steel pipes are widely used in various industries and applications due to their unique properties and characteristics.

Figure 8: Stainless steel

- **Characteristics of Stainless-Steel Pipes**
- **Corrosion resistance**
- **Durability:** Stainless steel is known for its exceptional durability and long service life

- **High strength:** Stainless steel pipes have excellent mechanical strength, allowing them to handle high-pressure and high-stress applications in industries
- **Heat resistance:** Stainless steel pipes can maintain their structural integrity and corrosion resistance at high temperatures
- **Hygiene and sanitation:** Stainless steel is easy to clean and maintain, making stainless steel pipes a preferred choice in industries such as food and beverage processing, pharmaceuticals, and healthcare
- **Carbon steel:** Is an alloy composed primarily of iron and carbon. Because of its strength and ability to withstand stress, carbon steel pipe is used in a variety of heavy-duty industries like infrastructure, ships, distillers, and chemical fertilizer equipment.

Figure 9: Carbon steel

- **Copper-Nickel:** Known for its corrosion resistance, especially in seawater environments. It's commonly used in marine and desalination systems.

Figure 10: Copper-Nickel

- **Aluminium:** Lightweight and corrosion-resistant, aluminium pipes are often used in aerospace and automotive industries, as well as in heat exchangers.

Figure 11: Aluminium

- **Pipe specifications**
- **Length:** Refers to the specified measurement of the pipe from one end to the other. The length is an important parameter because it determines how the pipe will be cut, transported, and installed. Anyone who works with steel pipe will be aware that it is generally sold in lengths of 21 feet (6.40 m)
- **Outside diameter (OD):** Refers to the measurement of the pipe's outer circumference. It plays a significant role in determining compatibility with fittings, valves, and the overall suitability for a specific application. It provides the reference size for a particular type of pipe.
- **Wall thickness range:** Wall thickness directly affects a pipe's strength, pressure rating, and suitability for various applications. Pipe thickness can also be specified in mm or inches to the value corresponding to that specified in the ASME standard. (ASME: American Society of Mechanical Engineers).

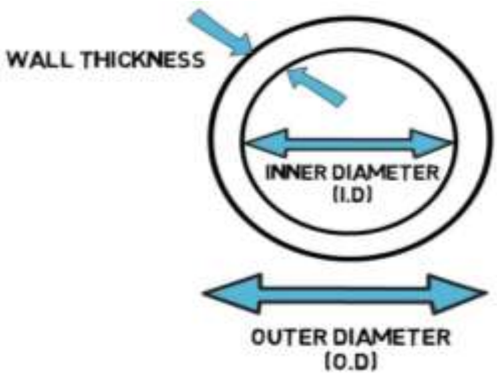


Figure 12: pipe specification

✓ **Plate metals**

Metal plates can be composed of different metals, including:

- Carbon Steel Plates (e.g., ASTM A516, A387)
- Stainless Steel Plates (e.g., ASTM A240, A276)
- Alloy Steel Plates (e.g., ASTM A387, A204)

- High-Strength Low-Alloy (HSLA) Steel
  The thickness of a metal plate is generally greater than that of a sheet metal but less than that of a slab. Plates are typically over 6 mm (0.25 inches) thick. Metal plates are usually cut into standard sizes or custom dimensions based on the application. They can be square, rectangular, or custom-shaped for specific projects.

Figure 13: Plate metals

✓ **Filler materials**

- **Welding wires:** Continuous metal wires used in processes like Gas Metal Arc Welding (GMAW/MIG) and Flux-Cored Arc Welding (FCAW). Can be solid or flux-cored, depending on the welding process. They come in various diameters and alloys. Examples:
- **ER70S-6:** Is a mild steel welding wire with good deoxidizing properties, used in MIG and TIG welding for producing high-strength welds with clean finishes.

Figure 14: MIG and TIG Welding wires

- **E:** Electrode (indicating it's used as a filler material in welding).
- **R:** Rod (meaning it can also be used as a welding rod in TIG welding).
- **70:** Refers to the tensile strength of the deposited weld metal, measured in ksi (thousand pounds per square inch). In this case, 70 ksi, or 70,000 psi.
- **S:** Solid wire (as opposed to a flux-cored wire).
- **6:** Refers to the specific chemical composition and characteristics of the wire, with "6" indicating that it contains higher levels of deoxidizers like silicon and manganese,

which help provide better weld quality, especially when welding on surfaces that may have mill scale or rust.

- **E71T-1:** Flux-cored wire used for welding in all positions, with good impact properties.

Figure 15: Flux-core welding wires

- **E**: Electrode, indicating that the material is used as a consumable electrode in welding.
- **7**: Refers to the tensile strength of the deposited weld metal, measured in 10,000 psi increments. In this case, 7 means a tensile strength of 70,000 psi.
- **1**: Position of the weld. The "1" indicates that the electrode is suitable for all positions (flat, horizontal, vertical, and overhead).
- **T**: Tubular, meaning it is a flux-cored wire, which contains flux inside the wire that helps shield the weld.
- **1**: Refers to the specific type of flux-cored wire. The number "1" indicates that the wire is suitable for single or multi-pass welding with a CO_2 or a 75-25 argon-CO_2 shielding gas mixture. It also typically has better performance for out-of-position welding.

- **Electrodes:** Conductive materials used in processes like Gas Tungsten Arc Welding (GTAW/TIG). They can be consumed or non-consumed, depending on the process. Made from tungsten or other materials for GTAW, providing a stable arc and precise control.

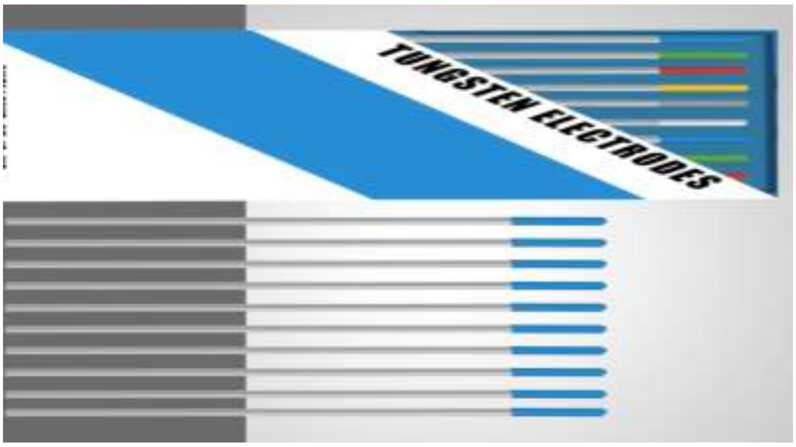


Figure 16: TIG electrode

✓ **Fluxes**

Fluxes are materials used in various welding and metalworking processes to promote the formation of a strong bond between the filler material and the base metal. They serve several critical functions, including cleaning the metal surfaces, protecting the molten weld pool from contamination, and facilitating the flow of the filler material.

- **Types of fluxes**

- **Solid Fluxes:** These are solid powders or granules applied to the surface of the base metal or filler material before or during welding. **Examples:**
  - **For SMAW (Stick welding):** The flux is incorporated into the electrode coating.
  - **For FCAW (Flux-Cored Arc welding):** The flux is present within the core of the flux-cored wire.

- **Liquid fluxes:** These are liquid solutions or pastes applied to the welding area or filler material. They are often used in processes where precise control of the flux application is required. **Examples:**

  For TIG welding: Liquid fluxes can be applied to help with the welding of certain metals like aluminium.

- **Powder fluxes:** These are dry, powdered fluxes that are spread over the base metal and filler material before welding. They are often used in processes like submerged arc welding.

- ✓ **Cleaning agents**

- **Degreasers:** Are cleaning agents used to remove grease, oil, and other contaminants from surfaces before welding or coating.
- **Solvents:** Are liquids used to dissolve or dilute other substances, such as oils or resins, for cleaning or preparation purposes.

- ✓ **Abrading materials**

- **Sandpaper:** Is an abrasive material used for smoothing and finishing surfaces by removing small amounts of material. It comes in various grits, with lower numbers for coarse sanding and higher numbers for fine finishing.
- **Grinding discs:** Are circular tools used with angle grinders or other power tools to grind, cut, or shape metal and other materials. They come in various types and grits to suit different grinding tasks and material hardness.

- ✓ **Shielding gases**

- **MIG/MAG and TIG gases**

  To prevent weld contamination and electrode deterioration the gas shield must,
- Prevent atmospheric contamination of the weld
- Not react with molten or solidifying weld metal or the tungsten electrode.

  Shielding gases are usually supplied in cylinders. These should be used in an upright position supported in a cylinder stand falling and causing accidents.
- **Inert gas:** Argon and helium are the mostly commonly used shielding gases for developing high quality weld joints of reactive and ferrous metals. Small amount of hydrogen or helium is often added in argon to increase the penetration capability and welding speed.

  Argon and helium are the mostly commonly used shielding gases for developing high quality weld joints of reactive and ferrous metals. Small amount of hydrogen or helium is often added in argon to increase the penetration capability and welding speed. These two inert gases as shielding gas are different in many ways. Some of these features are described in following section.
- **Argon (Arg):** Argon (Arg) Non-toxic used as a shielding gas, alone or mixed with other gases. Heavier than air and can accumulate at the base of any closed vessel being welded and can form layers at the bottom of the welding operation in a badly ventilated welding shop. Essential to have extraction and circulation of the atmosphere around the welding point, Suitable for most applications, Argon shielding gas is supplied in blue cylinders.
- **CO2 (carbon dioxide):** CO2; Argon is the main shielding gas used for TIG Welding and for MIG Welding Aluminium or MIG Brazing. CO2 produces a cooler, coarser, more spatter arc and a marginally harder weld. CO2 is a more challenging gas to use on thin material and not all MIG Welders perform well with 100% CO2 as a shielding gas.

- **Helium:** Helium: Non-toxic. Used generally mixed with other gases (e.g. 50% helium 50% argon). Helium is not produced in this country but is imported from the United States and is therefore much more expensive than argon. Gives better penetration and heat input. This gas is more expensive than argon and because of this is sometimes. used as a mixture of 5% helium and 95% argon for welding stainless steels. Helium shielding gas is supplied in brown cylinders.
- **FCAW gases**

  The primary purpose of a shielding gas in FCAW, as in any gas-shielded arc welding process, is to protect the arc and weld puddle from the contaminating effects of the atmosphere. If allowed to be exposed to the molten weld metal, the nitrogen and oxygen of the atmosphere can cause porosity and brittleness.

  In SMAW, protection is accomplished by placing an outer coating on the electrode, which produces a gaseous shield as the coating disintegrates in the welding arc. In FCAW, the same effect is accomplished by decomposition of the electrode core, or by a combination of this and surrounding the arc area with a shielding gas supplied from an external source.

  A shielding gas displaces air in the arc area. Welding is then accomplished under a blanket of shielding gas, and since the molten weld metal is exposed only to the shielding gas, the atmosphere does not contaminate it.

  Therefore, Inert and active gases may be used for FCAW process. Active gases, such as carbon dioxide, argon-oxygen mixtures, and argon-carbon dioxide mixtures are used for almost all applications, with carbon dioxide being the most common. Active gases are not chemically inert and can form compounds with the metals. Since almost all flux cored arc welding is done on ferrous metals, this is not a problem.

  The choice of the proper shielding gas for a specific application is based on:
- Type of metal to be welded
- Arc characteristics and metal transfer
- Availability
- Cost of the gas
- Mechanical property requirements
- Penetration and weld bead shape
- **Carbon Dioxide**

  Carbon dioxide is manufactured from fuel gases that are given off by the burning of natural gas, fuel oil, or coke. The carbon dioxide given off by the manufacturing of ammonia and the fermentation of alcohol is almost 100% pure.

  Carbon dioxide is made available to the user in either cylinder or bulk containers, with the cylinder being more common. With the bulk system, carbon dioxide is usually drawn off as a liquid and heated to the gas state before going to the welding gun.

The bulk system is only used when supplying a large number of welding stations. In the cylinder, the carbon dioxide is in both a liquid and a vapor form, with the liquid carbon dioxide occupying approximately two thirds of the space in the cylinder, as shown in Fig.2.7
By weight, this is approximately 90% of the content of the cylinder. Above the liquid, it exists as a vapor gas. As carbon dioxide is drawn from the cylinder, it is replaced with carbon dioxide that vaporizes from the liquid in the cylinder; therefore, the overall pressure will be indicated by the pressure gauge. When the pressure in the cylinder has dropped to 200 psi (1.4 MPa) the cylinder should be replaced.

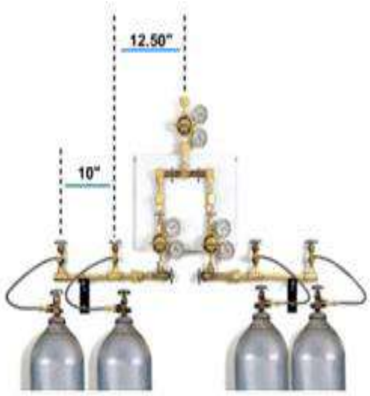


Figure 17: carbon dioxide gas cylinder

When flow rates higher than 12 L/min. are required, normal practice is to manifold two CO2 cylinders in parallel, or to place a heater between the cylinder and gas regulator, pressure regulator, and flow meter. *Figure2.8* shows a manifold system used for connecting several cylinders together. Excessive flow rates can also result in drawing liquid from the cylinder.
Carbon dioxide is the most widely used shielding gas for FCAW. Most active gases cannot be used for shielding, but carbon dioxide provides several advantages for use in welding steel, such as deep penetration, low cost, and it promotes a globular transfer.

- **Argon-Carbon Dioxide Mixtures**
  Argon and carbon dioxide are sometimes mixed for use with FCAW. A high percentage of argon gas in the mixture tends to promote a higher deposition efficiency due to creating less spatter. This mixture also creates less oxidation and lower fumes. The most commonly used argon-carbon dioxide mixture contains 75% argon and 25% carbon dioxide. This gas mixture produces a fine globular metal transfer that approaches a spray.

It also reduces the amount of oxidation that occurs, compared to pure carbon dioxide. The weld deposited in an argon-carbon dioxide shield generally has higher tensile and yield strengths. Argon-carbon dioxide mixtures are often used for out-of-position welding, achieving better arc characteristics and welder appeal. This mixture also improves arc transfer on smaller diameters. Argon/CO_2 is often used on low-alloy steels and stainless steels.

- **Argon-oxygen mixture**
  Argon-oxygen mixtures containing 1 or 2% oxygen are used for some applications. Argon-oxygen mixtures tend to promote a spray transfer that reduces the amount of spatter. A major application of these mixtures is in welding stainless steels where carbon dioxide can cause corrosion problems.

- **Tools**
  - ✓ **Measuring tools**

Measuring tools are essential for ensuring accuracy in pipe and pressure vessel welding. Common measuring tools include:

- **Tape measure**: Used for measuring lengths and dimensions of pipes and fittings.
- **Calipers**: Used to measure the diameter of pipes, wall thickness, and other precise dimensions.
- **Micrometers**: Provide accurate measurements of pipe thickness and other small dimensions.
- **Protractors**: Used to measure and set angles for pipe alignment and fitting.

✓ **Marking tools**

Marking tools help in marking cuts, weld lines, and alignment points on pipes and plates. Common marking tools include:

- **Chalk or soapstone**: Provides temporary markings on metal surfaces that are easily visible and removable.
- **Scribe**: A tool used to make precise markings on metal surfaces, often used for layout work.
- **Center punch**: Used to create indentations on metal surfaces to mark drill points or reference lines.

✓ **Cutting tools**

Cutting tools are used to cut pipes, plates, and other metal components to the required size and shape. Common cutting tools include:

- **Pipe cutters**: Designed for cutting pipes, often used in a rotary motion for clean, straight cuts.

Figure 18: Pipe cutters

- **Angle grinders**: Equipped with cutting discs, they are versatile for cutting through metal plates and pipes.
- **Oxy-acetylene torches**: Use a flame to cut through metal, suitable for thicker pipes and plates.

✓ **Clamping tools**

Clamping tools are used to hold pipes, plates, and fittings in place during welding. Common clamping tools include:

- **Pipe clamps**: Designed to hold pipes securely in place during welding or assembly.
- **C-clamps**: Versatile clamps that can secure metal parts and fixtures to prevent movement.
- **Welding clamps**: Specifically designed to hold metal pieces together during the welding process.

✓ **Common tools**

- **Wrenches**: Used for tightening or loosening bolts and nuts on pipe fittings and other components.
- **Pliers**: Useful for gripping, bending, and manipulating metal parts.
- **Hammers**: Used to adjust or align metal pieces and to remove weld spatter or slag.
- **Wire brushes**: For cleaning metal surfaces before welding to ensure good adhesion and reduce contamination.

- **Equipment**

- ✓ **MIG/MAG welding equipment**

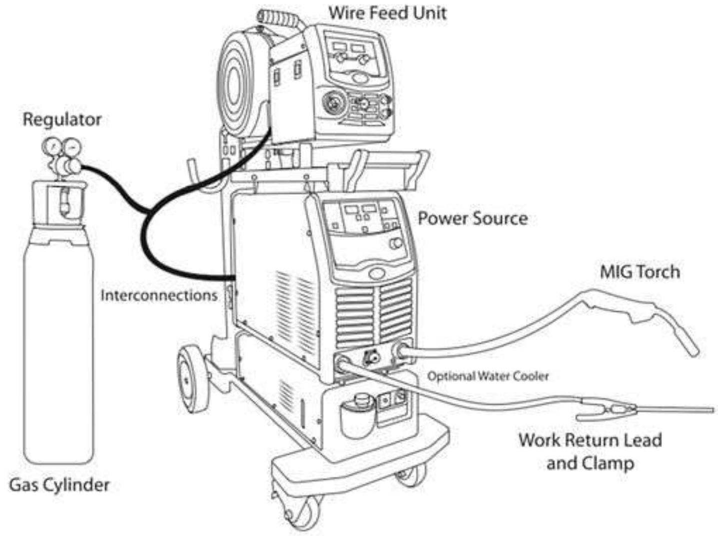


Figure 19: MIG/MAG welding equipment

- **Types of MIG/MAG Welding machine**: MIG/MAG Welding machines are classified into 3 main categories which are:

AC MIG/MAG Welding machine.

- Rated output voltage: 25.26V
- Length: 420 mm, large:310 mm, Width: 210mm
- Input voltage: 220V
- Power:50/60 Hz
- Rated output current:220-240V (110v support)

DC MIG/MAG Welding machine

- Input capacity: 6.16 KVA
- Rated voltage: 220-240v~50/60HZ
- **AC/DC MIG/MAG Welding machine**
- MIG/MAG AC/DC 250AMP
- L=320mm l=180mm
- Input voltage= 220V
- Rated output current: 220-240V

Figure 20: AC/DC MIG/MAG Welding machine

- **Shielding gas cylinder**
- **Argon (Arg):** Argon (Arg) Non-toxic used as a shielding gas, alone or mixed with other gases. Argon shielding gas is supplied in blue cylinders.
- **CO2 (carbon dioxide):** CO2; Argon is the main shielding gas used for TIG Welding and for MIG Welding aluminium or MIG Brazing. CO2 produces a cooler, coarser, more spatter arc and a marginally harder weld.

  CO2 is a more challenging gas to use on thin material and not all MIG Welders perform well with 100% CO2 as a shielding gas. In many countries, CO2 cylinders are often colored green and, in some regions, black is used to identify CO2 cylinders.

  Helium: Helium**:** Non-toxic. Used generally mixed with other gases (e.g. 50% helium 50% argon). used as a mixture of 5% helium and 95% argon for welding stainless steels. Helium shielding gas is supplied in brown cylinders.
- **Regulator**

  The function of the gas regulator is to reduce the bottle pressure gas down to a lower pressure and deliver it at a constant flow. The constant flow of gas is fed to the feeder then through the interconnection to the hand piece, down the hand piece to the weld area.

  Different gases don't always use different fittings, so check with your supplier what type you will need. As well as different types of regulators for different gases there are also different styles of regulator as well.

  The two main ones are regulators with flow tube left figure and without flow tube right figure. Both regulators do the same job, but have a different way of setting the gas flow. The amount of gas flow needed to do the job will depend on the welding gas and the job being done, but a common setting to start with is 10L/min.

Figure 21: Regulator

- **MIG/MAG Torch**

1. Components

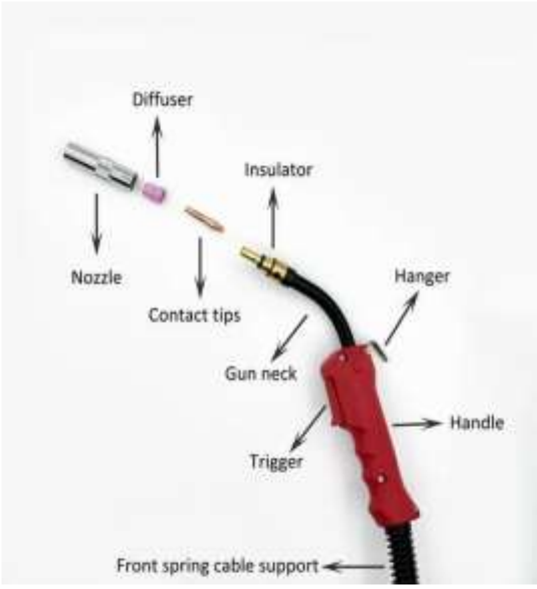


Figure 22: MIG/MAG Torch components

- **Handle:** The operator grips the torch here, which is designed for comfort and control.
- **Trigger:** Activates the welding arc and wire feed; many torches have a safety trigger to prevent accidental activation.
- **Gas diffuser:** Distributes shielding gas evenly around the weld area to protect the molten metal.
- **Contact tip:** The part through which the welding wire is fed; it conducts electricity to the wire and helps maintain a stable arc.
- **Nozzle:** Surrounds the contact tip and directs the flow of shielding gas to the weld area. Different nozzle sizes can be used depending on the application.

2. Types

- **Standard MIG torch:** Used for general-purpose welding, suitable for various materials.

Figure 23: Standard MIG torch

- **Push-pull torch:** Features a mechanism that pulls the wire through the torch, reducing friction and improving wire feed, especially for aluminium.

Figure 24: Push-pull torch

- **Cables**

1. Types

- **Power cable:** Connects the torch to the welding machine, carrying electrical current to the contact tip.

Figure 25: Power cable

- **Gas hose:** Supplies the shielding gas from the cylinder to the torch. Typically made of flexible rubber or plastic.

Figure 26: Gas hose

- **Ground cable:** Connects the workpiece to the welding machine to complete the electrical circuit.

Figure 27: Ground cable

- **Feed Wire**

  1. Types

  Solid Wire: Commonly used for MIG welding; available in various diameters and materials (e.g., ER70S-6 for mild steel).

  Flux-Cored Wire: Often used in MAG welding; contains a flux core that provides additional protection and can be used without shielding gas.

  2. Characteristics

  Diameter: Typically ranges from 0.023 to 0.045 inches, depending on the application and material.

  Material: Chosen based on the base metal; options include mild steel, stainless steel, and aluminium.

  3. Feeding mechanism

  The wire is fed through the torch using a motorized feeder, which maintains a consistent and controlled wire feed rate for optimal welding performance.

Figure 28: wire feeding mechanism

✓ **FCAW (Flux-Cored Arc Welding) equipment**

The equipment used for FCAW is very similar to that used for GMAW. The basic FCAW welding equipment consists of a Power source (Welding machine), gas cylinder, controls, wire feeder, welding gun and welding cables. A major difference between the gas-shielded electrodes and self - shielded electrodes is that the gas shielded wires also require a gas shielding system.

This may also have an effect on the type of welding gun used. Fume extractors are often used with this process. For machine and automatic welding, several items, such as seam followers and motion devices, are added to the basic equipment.

- **FCAW welding machine**
- **Generator and alternator welding machines**

Generator welding machines used for this process can be powered by an electric motor for workshop use, or an internal combustion engine for field applications. Gasoline or diesel engine-driven welding machines have either liquid or air-cooled engines and many of them provide auxiliary power for emergency lighting, power tools, etc.

Many of the engine-driven generators used for FCAW in the field are combination constant current-constant voltage types. These types are popular for applications where both SMAW and FCAW can be accomplished using the same power source. Figure 2.9 shows an engine-driven generator machine used for flux cored arc welding. The motor-driven generator welding machines are gradually being replaced by transformer-rectifier welding machines.

Figure 29: Generator and alternator welding machines

Motor-driven generators produce a very stable arc, but they are noisier, more expensive, consume more power and require more maintenance than transformer-rectifier machines. They can, however, function without being sourced by an electrical power supply and, in fact, can produce the auxiliary electricity during power outages. An alternator welding machine is an electric generator made to produce AC power. This power source has a rotating assembly. These machines are also called rotating or revolving field machines.

- **Transformer welding machines**

Transformer-rectifiers are the most widely used welding machines for FCAW. Adding a rectifier to a basic transformer circuit is a method of supplying direct current to the arc without using a rotating generator. A rectifier is an electrical device which changes alternating current into direct current. These machines are more efficient electrically than motor-generator welding machines and they provide quieter operation.

Figure 30: Transformer welding machines

There are two basic types of transformer-rectifier welding machines: those that operate on single phase input power and those that operate on three-phase input power. The single-phase transformer-rectifier machines provide DC current to the arc and a constant current volt-ampere characteristic, but are not as popular as three-phase transformer-rectifier welding machines for FCAW.

When using a constant current power source, a special variable speed or voltage-sensing wire feeder must be used to maintain a uniform current level. A limitation of the single-phase system is that the power required by the single-phase input power may create an unbalance of the power supply lines which is objectionable to most power companies. These machines normally have a duty cycle of 60%.

The most widely used type of power source for this process is the three-phase transformer-rectifier. These machines produce DC current for the arc, and for FCAW, most have a constant voltage volt-ampere characteristic. When using these constant voltage machines, a constant speed wire feeder is used.

This type of wire feeder maintains a constant wire feed speed with slight changes in welding current. The three-phase input power gives these machines a more stable arc than single phase input power and avoids the line unbalance that occurs with the single-phase machines.

Many of these machines also use solid state controls for the welding. A 650amp solid state-controlled power source is shown in Figure 2.10. This machine will produce the flattest volt-ampere curve of the different constant voltage power sources. Most three-phase transformer-rectifier power sources are rated at a 100% duty cycle.

Wire feeders

- The wire feed motor provides the power for driving the electrode through the cable and gun to the work. There are several different wire feeding systems available. The selection of the best type of system depends on the application. Most FCAW wire feed systems are the constant speed type, which are used with constant voltage power sources. This means the wire feed speed is set before welding.
- The wire feed speed controls the amount of welding current. Variable speed or voltage-sensing wire feeders are used with constant current power sources. With a variable speed wire feeder, a voltage-sensing circuit maintains the desired arc length by varying the wire feed speed. Variations in the arc length increase or decrease the wire feed speed.
- A wire feeder consists of an electrical motor connected to a gear box containing drive rolls. The gear box and wire feed motor shown in Figure 2.11 have four feed rolls in the gear box. While many systems have only two, in a four-roll system, the lower two rolls drive the wire.
- Because of their structure, flux-cored wires can be easily flattened. The type of drive roll used is based on the size of the tubular wire being fed.
- The three basic types of drive rolls are the:

- **"U" groove,**
- **"V" knurled,**
- **"U" cogged,**

As shown in Figure2.12. "U" groove drive rolls are only used on small diameter wires. These can be used because small diameter tubular wires are less easily flattened. "V" knurled drive rolls are most commonly used for wire sizes 1/16 in. (1.6 mm) and greater. These drive rolls are lightly knurled to prevent slipping of the wire. The "U" cogged drive rolls are used for large diameter flux-cored wires. A groove is cut into both rolls. Different gear ratios are used, depending on the wire feed speed required.

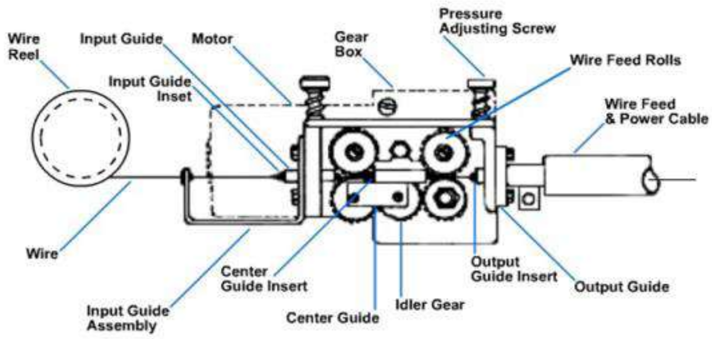


Figure 2.11. Wire feed assembly

Figure 2.12. Drive roll types and applications.

Figure 31: wire feed assembly

Wire feed systems may be the pull, push, or push-pull type, depending on the method of application and the distance between the welding gun and the coil or spool of wire.

- Pull type wire feeders have the drive rolls attached to the welding gun. Most machine and automatic welding stations use this type of system, but pull type wire feeders are rarely used in semi-automatic welding. Pull type wire feeders have the advantage for welding small diameter aluminum and soft nonferrous metals with GMAW because it reduces wire feeding problems, but, since most flux-cored wires are steel, this is not an advantage for FCAW.
- The push type system with the drive rolls mounted near the coil or spool of wire is the most commonly used wire feed method for semi-automatic welding (*Figure*

2.13). The wire is pulled from the coil or spool and then pushed into a flexible conduit and through the gun. The relatively large diameter wires used in FCAW are well suited to this type of system. The length of the conduit can be up to about 12 feet (3.7m). Another advantage of this push type system is that the wire feed mechanism is not attached to the gun, which reduces the weight and makes the gun easier to handle.

- Some wire feed systems contain a two-gun, two wire feeder arrangement connected to a single control box, which is connected to a single power source. Both wire feeders may be set up, and there is a switch on the control to automatically select which of the two systems will be used. One advantage to this system is that the second wire feeder and gun can provide backup in case of breakdown, gun maintenance, or electrode change.

Figure 32: semi-automatic solid state control wire feeder

Another advantage is that two different electrodes for different applications can be set up. For example, a GMAW electrode and gun can be set up on one schedule for welding a root pass, and a second schedule can be set up with a flux-cored wire to weld the rest of the joint with FCAW's faster deposition. This eliminates the need for two power sources or the need to change the electrode wire and gun.
The liner is made of flexible metal and is available in sizes compatible with the electrode size. The liner guides the electrode wire from the wire feeder drive rolls through the cable assembly and prevents interruptions in the travel.

- **FCAW welding guns**

The welding guns sometimes referred as a welding torch are the equipment used to deliver the welding wire, welding current and shielding gas to the welding arc during the FCAW welding process. Guns are available for semi-automatic operation and for automatic operation, where they are fixed in automatic welding head.
They are two types of guns available which are:

- Air-cooled guns
- water-cooled welding guns

Heavy-duty welding guns are normally used because of the large size electrode wires typically used and the corresponding high welding current levels required. Because of the intense heat created by this process, heat shields are attached to the gun in front of the trigger to protect the welder's hand.

Both air-cooled and water-cooled guns are used for FCAW. Air-cooled guns are cooled primarily by the surrounding air, but when a shielding gas is used, this will have an additional cooling effect.

A water-cooled gun is similar to an air-cooled gun, except those ducts to permit the water to circulate around the contact tube and nozzle have been added. Water-cooled guns permit more efficient cooling of the gun. Figure 33 right. shows a 500-ampere water cooled gun.

Figure 33: water cooler welding gun (left) and air-cooled welding gun (right)

Water-cooled guns are preferred for many applications using 500 amperes and recommended for use with welding currents greater than 600 amperes. Welding guns are rated at the maximum current capacity for continuous operation.

Air-cooled guns are lighter and easier to manipulate. Figure 33 right shows a 350-ampere air-cooled welding gun.

Note: The equipment and set-up for FCAW Welding is very similar to that of gas metal arc welding (GMAW), the major difference in the equipment is that with Gas metal arc welding (GMAW), a shielding gas is always required whereas the FCAW welding process can be done with or without a shielding gas. Therefore, the welding guns for FCAW is also very similar to that of GMAW, the figure 34 shows the typical parts of welding gun used in FCAW and/or GMAW process.

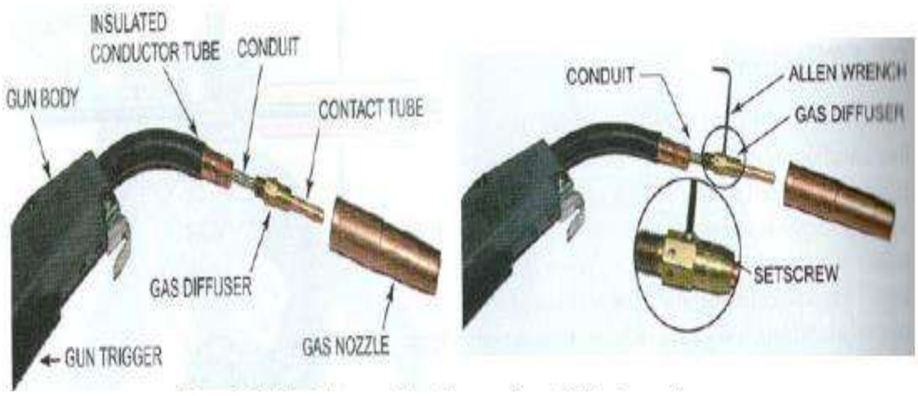


Figure 34 welding gun parts

Some self-shielded electrode wires require a specific minimum electrode extension to develop proper shielding, so welding guns for these electrodes have guide tubes with an insulated extension guide. This guide supports the electrode and ensures a minimum electrode extension.

- **Fume extractors**

Fume extractors are often used to help reduce the smoke levels produced by flux-cored electrodes.

This reduces air pollution and gives better visibility. Welding guns can be equipped with a fume extractor that consists of an exhaust nozzle that encircles the gun nozzle, as shown in Figure 35.

The nozzle is connected to a filter and an exhaust pump. The fume extraction nozzle should be located at a distance far enough from the arc to draw in the rising fumes without disturbing the shielding gas flow.

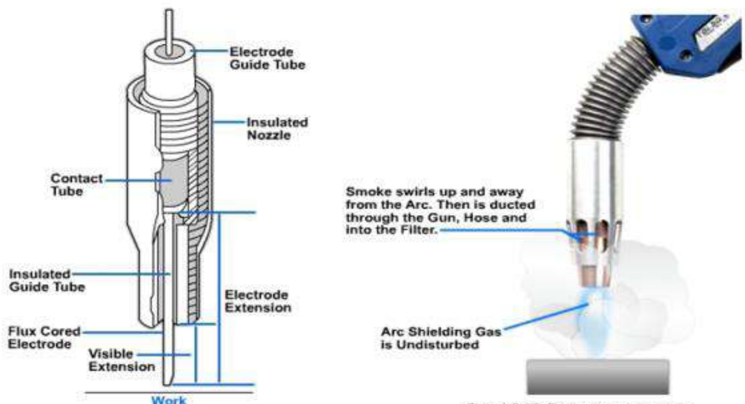


Figure 2.17. Insulated extension guide

Figure 2.18. Fume extractor nozzle

Figure 35: Fume extractors

The major advantage of this fume extraction system is that it is always close to the point of welding. A portable fume exhaust fan cannot be positioned as close to the arc, and requires repositioning for every change in welding position.

The disadvantage of the fume extractor is that it makes the gun bulkier(massive) and more difficult to manipulate. Fume extractors are generally not necessary in a welding booth that is well ventilated.

- **Flowmeter and regulator**

A regulator is an equipment of FCAW welding process which is used to reduce the pressure from the gas supply source and maintain a constant delivery pressure. Flowmeter is an equipment used to control the flow of gas from the regulator to the welding gun.

Figure 36: Flowmeter and regulator

A valve at the flowmeter outlet adjusts the gas flow rate. The flowmeter may be often attached to the regulator, as shown in Figure 36. Regulators and flowmeters are designated for use with specific shielding gases and should only be used with the gas for which they were designed.

Accessories used in FCAW welding

- Welding accessories used in FCAW welding process are: Cylinder key, tong, wire brush, adjustable spanner, anti-spatters, hand shield or helmet, chipping hammer.

  ✓ **TIG welding equipment**

- **DC welding machine**

Figure 37: DC welding machine

A DC TIG welding machine must be presented with the most following characteristics:

Pulse control: Built in pulsing functions help minimize heat input on thin materials, and provide for a faster freezing weld puddle for uphill welding on curved surfaces such as process piping. The TIG pulse also helps moderate filler metal deposition for consistent bead appearance.

High-frequency TIG starting: Makes it easy to establish an arc under a variety of conditions. Enhances quality by minimizing the potential for weld contamination created by tungsten inclusions in the weld.

Powerful with heavy duty power sources at maximum output current: 200A.

Easy operation and full functions: from the control panel allowing fast adjustment of all necessary controls for DC Pulse TIG welding with either HF (High frequency) or contact ignition.

Advantages of using TIG welding machine:

- DC TIG Machines is more Advantages for repair and construction work: Minimal size and weight, low energy consumption and generator-usability.
- Versatile working on small parts and extra flexibility due to the G 160-torch of castolin TIG.
- Easy-to-use by menu guides and simple touch-panel.
- Clear readable digital-display for programming and status.
- The electronic high-frequency-ignition ensures perfect, contact free ignition on all applications.
- Lift-Arc-ignition for welding in areas with sensitive electronics, e.g. control and steering systems.
- Standard-integrated pulse function for improved welding pool control especially on thin sheets.
- All parameters for professional TIG-welding are directly accessible.

DC/AC welding machine

AC/DC machine is built on the base of the digital system, which offers precise, expert AC/DC TIG welding process. It's a precise welding specialist that suits all welded materials. - Modular design allows you to build the package that best suits your needs. - Easy operation and full functions: From the control panel allowing fast adjustment of all necessary controls for DC, AC TIG welding with either HF or contact ignition. It's also very convenient to store or call out the welding parameters from the memory channels by pressing the Job and Save button.

Figure 38: DC/AC welding machine

- ✓ **Shielding gas cylinder.**

A shielding gas cylinder is a storage container specifically designed to hold compressed gases used in welding processes like MIG (Metal Inert Gas), TIG (Tungsten Inert Gas), and FCAW (Flux-Cored Arc Welding). The primary purpose of the shielding gas is to protect the weld area from atmospheric contamination, such as oxygen, nitrogen, and water vapor, which can weaken the weld quality. Shielding gas cylinders are typically made from steel or aluminium to withstand high-pressure storage.

Figure 39: Gas cylinder

Color Coding: Shielding gas cylinders are color-coded for easy identification of the gas type. For example:

- **Blue**: Argon
- **Brown**: Helium
- **Green**: Oxygen
- **Gray**: Carbon Dioxide

Precautions on shielding gas cylinder

- They should always be stored and transported in an upright, secure position to prevent accidents.
- Cylinders should not be exposed to heat or flames as this could cause the gas to expand, increasing the risk of explosion.

✓ **Flowmeter.**

Flowmeter is back pressure compensated help to ensure accurate readings when line restrictions are present. Simple to operate and convenient to use. Long service life with 2-inch pressure gauge design.

Figure 40: Flowmeter

Flowmeter is designed to be fitted to the outlet of an argon or CO2 regulator to provide greater control of the flow of your shielding gas through the gas line. Ideal for use in MIG and TIG. 2 categories of flowmeter are available with either *,0–15 LPM* or *0-40 LPM* flow rate.

- ✓ **TIG hoses.**

The correct and most popular method for the short distance transport of inert shielding gases form regulator to MIG or TIG welding machine. Durable PVC, diameter that can be used with hose tail and appropriate nuts. It is recommended that the correct hose clips are used rather than jubilee clips.

Figure 41: TIG hoses

Clear braided hose is a very popular and versatile hose product. Often used in water recirculation attached to cooler inlet and outlet fittings, or as an alternative to using the proper black argon hose for the short transport of inert shielding gases from regulator to MIG or TIG machine.

- ✓ **TIG accessories.**

No	TIG Accessories name	Accessories definition and description

1	**TIG welding Nozzles** 	Alumina and others nozzles fit all TIG welding torches with their recommended size for TIG welding process.
2	**Collet for TIG Torch** 	Collet 2.4mm for T-150, T-161 and T-200 TIG torch.
3	**Collet body for TIG-Torch** 	Collet body 2.4mm for T-150, T-161 and T-200 TIG torch size.
4	**Long back cap for TIG-torch** 	Long back cap for T-150, T-161 and T-200 TIG torch.
5	**TIG welding pedal control** 	TIG welding control pedal for TIG welders pin connector. improved low-current welding with patented design, for adjustment of welding current during TIG welding.

6	**Ground Cable & Clamp Assembly**  	Fits all machines with a large dinse connector.
7	**Short back cap for TIG Torch** 	Short back cap for T-150, T-161 and T-200 TIG torches.
8	**TIG Torches (especially T-150 w.dix 25 connector).** 	The T-150 torch is a lightweight torch well adapted to general applications onboard.
9	**TIG Pats Kits** 	These handy TIG Parts Kits for Series 9, 17,18, 20 & 26 Torches include everything you need for those critical welding jobs. And the box is a great way to keep those parts organized, easy to find and easy to re-order. Each kit includes one of each of the following: 2% Ceriated Tungsten, 1½% Lanthanotid

		Tungsten, collet, collet body and alumina cup.
10	**Temporarily out of stock** 	our heavy-duty welding cart features an enclosed storage box for accessories, such as consumable kits, welding gloves, and welding helmets. The cart only includes one tray (the top tray), but you can utilize the space on top of the storage box to set up a water-cooler, a small stick welder, or a small plasma cutter.
11	**TIG Welding Gloves** 	Getting the perfect weld isn't just about the right equipment, it's about you too. Any welding job is easier and the finished result is better when you are comfortable and have the correct "feel". That's where our

		premium quality TIG Welding Gloves come in. They're soft and supple, giving you a superior level of control and making it easier for you to work the filler rod.
12	**Gas Lens Kit:**  	If you're looking for better shield gas coverage patterns, then our Gas Lens Kit is for you. Better shielding gas patterns let you extend the electrode beyond the edge of the gas cup, which enable you to get into tight spaces or corners. There are several kit variations available; please see the descriptions below. All of the kits below include aluminum Cups and Gas Lens Collet Bodies in the following sizes: .040", 1/16", 3/32", and 1/8". Available for 9, 17, 18, 20, and

		26 Series TIG torches.

✓ **Cutting equipment**

- **Shearing machine**: Used for cutting straight lines in sheet metal or other flat materials. It uses blades to cut through the material without producing significant heat or distortion.

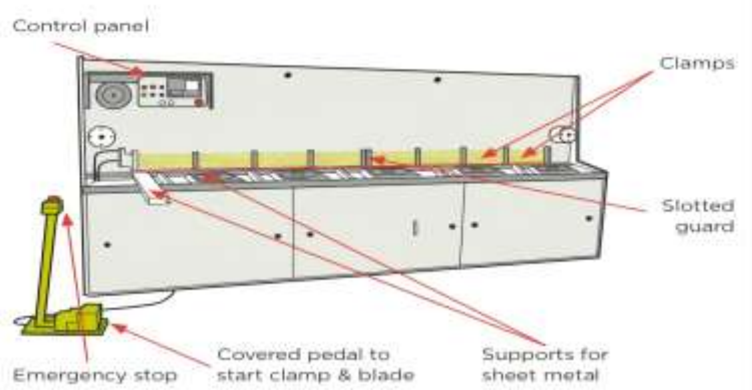


Figure 42: Shearing machine

- **Cut off machine**: A portable, high-speed saw used for cutting pipes, rods, or other metal sections. It often uses an abrasive disc to cut through the material.

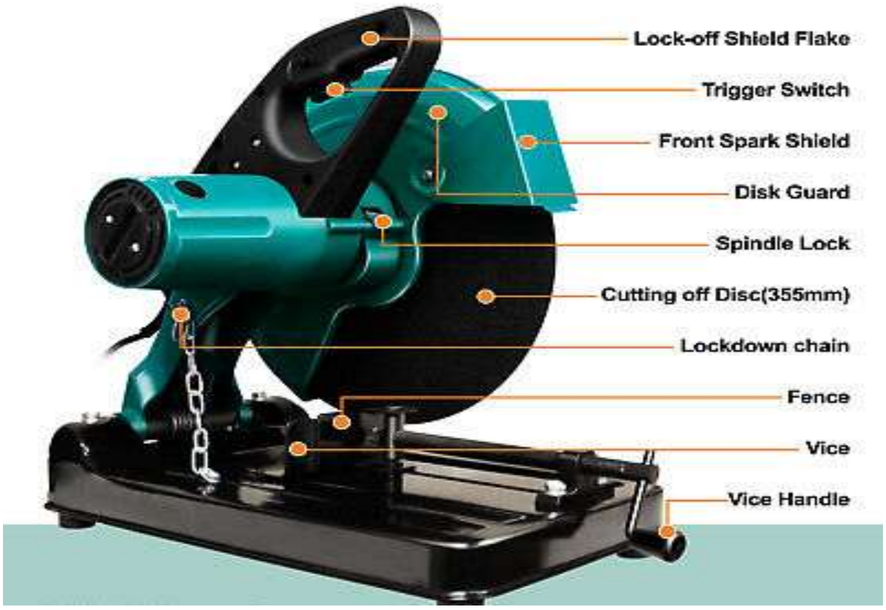


Figure 43: Cut off machine

- **Angle grinder**: A versatile tool equipped with various discs for grinding, cutting, and polishing metal surfaces. It is commonly used for cutting and finishing tasks.

Figure 44: Angle grinder

- **Plasma cutter**: Uses a high-velocity jet of ionized gas (plasma) to cut through metal. It is capable of cutting a wide range of metals with precision and speed.

Figure 45: plasma machine

- **Laser cutter**: Employs a focused laser beam to cut through metal with high precision. It is ideal for intricate and detailed cuts in various thicknesses of metal.

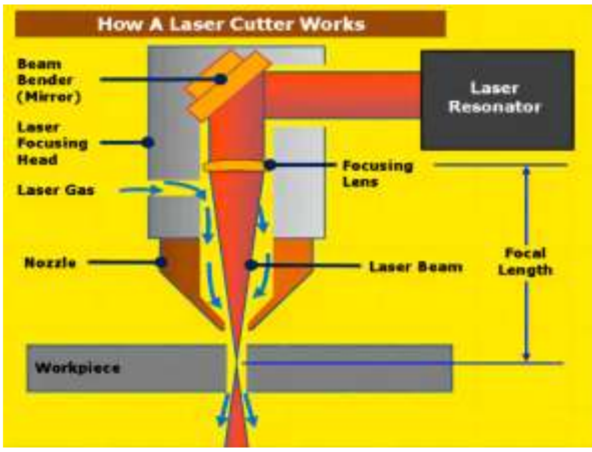


Figure 46: laser torch parts

- **Oxy-acetylene gas cutting equipment**: Uses a flame produced by burning acetylene with oxygen to cut through metal. It is suitable for cutting thick metal sections and is often used in heavy industrial applications.

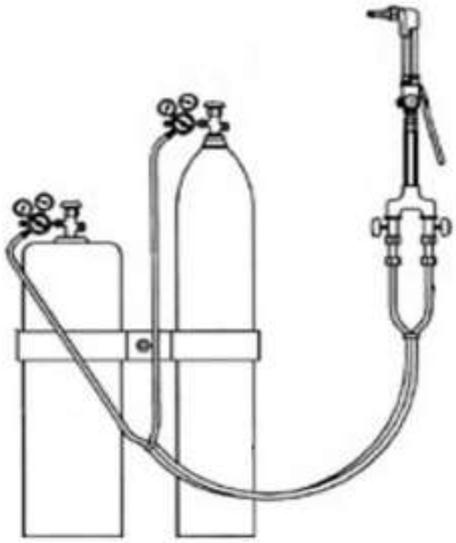


Figure 47: Oxy-acetylene gas cutting equipment

- ✓ **Forming equipment**

- **Rolling machine**: Used to bend and form metal sheets into cylindrical or curved shapes. It typically involves passing the metal through rollers to achieve the desired curvature.

Figure 48: Rolling machine

- **Folding machine**: Also known as a brake, it is used to make precise bends or folds in metal sheets. It clamps the metal and bends it along a straight line to create angles or other shapes.

Figure 49: Folding machine

- ✓ **Welding table**

- **Welding table**: A heavy-duty work surface designed to support and stabilize metal workpieces during welding. It often has built-in clamps, a flat surface for accurate alignment, and sometimes a grid or markings for measuring and positioning.

Figure 50: Welding table

- ✓ **Fume extractor**

- **Fume extractor**: Equipment designed to capture and remove harmful fumes, gases, and particulates generated during welding and cutting processes. It helps maintain a safe and clean working environment by filtering out hazardous substances and improving air quality.

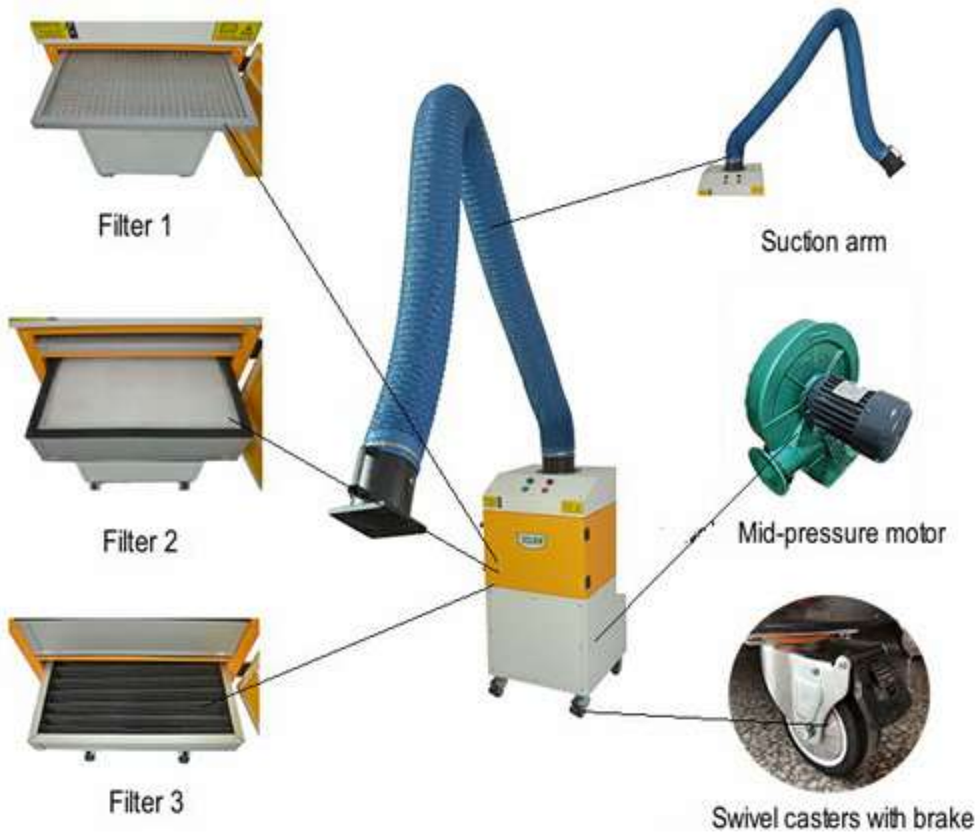


Figure 51: Fume extractor

- **Selection factors of materials, tools and equipment as required in pipes and pressure vessels welding.**

✓ **Selection of Materials**

Materials for pipes and pressure vessels must meet specific mechanical, chemical, and environmental requirements. Key factors include:

- **Material Compatibility:** Choose materials compatible with the welding process and service environment (e.g., carbon steel, stainless steel, alloy steels, etc.).
- **Mechanical Properties:** Ensure materials meet the required strength, ductility, hardness, and toughness, especially for pressure vessels.
- **Corrosion Resistance:** Materials should resist the environmental conditions they will be exposed to, such as high pressure, temperature, or corrosive fluids.
- **Weldability:** Materials should have suitable weldability characteristics to ensure proper bonding during welding, reducing the risk of defects like cracking or porosity.
- **Temperature Resistance:** In pressure vessels, materials need to maintain their strength and stability at high temperatures, considering both operation and potential thermal expansion.
- **Certification and Standards:** Ensure materials meet industry standards and codes (e.g., ASME, API) for safety and reliability.

✓ **Selection of Tools for Welding**

The selection of tools for welding, including welding machines and hand tools, depends on the specific welding process and the material being welded. Considerations include:

- **Type of Welding Process:** The tools should be compatible with the chosen welding process (e.g., Shielded Metal Arc Welding (SMAW), Gas Tungsten Arc Welding (GTAW), Submerged Arc Welding (SAW), etc.).
- **Power and Capacity:** Ensure welding machines have the appropriate power capacity to handle the thickness and material type of pipes and vessels.
- **Electrode Type:** Select the right type of electrode based on the material being welded and the desired weld characteristics (e.g., stick electrodes for SMAW, filler rods for GTAW).
- **Precision and Control:** Tools should provide sufficient control over the heat and speed of welding to avoid defects, particularly in critical pressure vessel welds.
- **Portability:** In some cases, tools need to be portable for fieldwork (e.g., for pipeline welding), requiring lightweight and easy-to-move equipment.
- **Ease of Maintenance:** Tools should be durable and easy to maintain, ensuring minimal downtime and reducing repair costs.

✓ **Selection of Equipment**

The choice of welding equipment is crucial to ensuring efficient, high-quality welding and safety. Key factors include:

- **Welding Machines/Power Sources:** Choose machines with adequate power output (AC/DC) to suit the welding process and material.AC or DC: DC is preferred for most welding applications, but some materials (like aluminum) may require AC.
- **Pulse Capabilities**: For thin materials or high-precision work, machines with pulse features may be needed to reduce heat input.
- **Welding Positioners:** Positioners help hold pipes or pressure vessels in the correct orientation, especially for large diameter or heavy components, improving weld quality and accessibility.
- **Protective Equipment:** Ensure proper Personal Protective Equipment (PPE) like welding helmets, gloves, and aprons to protect workers from heat, sparks, and UV radiation.
- **Welding Helmets:** Auto-darkening helmets are preferred for better visibility and protection.
- **Gloves and Clothing:** Heat-resistant gloves, flame-retardant clothing, and protective footwear are essential.
- **Fume Extraction and Ventilation Systems**: Proper ventilation is necessary to protect welders from harmful fumes and gases. Welding fume extractors or a well-ventilated workspace are critical for health and safety.

- **Inspection and Testing Equipment:** Non-destructive testing (NDT) equipment such as ultrasonic, radiographic, or visual inspection tools are necessary to ensure weld quality and detect defects after welding.
- **Preheating and Post-Weld Heat Treatment (PWHT) Equipment**: Some materials, especially high-strength alloys, require preheating to reduce stress and post-weld heat treatment to relieve residual stresses.
- **Automation or Robotic Systems:** In some cases, automated or robotic welding systems are selected for consistency, high production rates, and precision, particularly in large-scale manufacturing of pressure vessels.

Practical Activity 1.3.2: Selecting materials, tools and equipment used in pipes and pressure vessels welding

Task:

You are requested to go in manufacturing workshop and select materials, tools and equipment required for the work in pipes and pressure vessels welding based on selection criteria.

1: Apply safety precautions

2: Select materials, tools and equipment required for the work.

3: Present your work to the trainer and whole class.

4: Read key reading 1.3.2 and ask clarification where necessary.

5: Perform the task provided in application of learning 1.3.

Key readings 1.3.2: Selecting materials, tools and equipment used in pipes and pressure vessels welding

- **Procedure for selecting materials, tools, and equipment for welding pipes and pressure vessels**

✓ **Material selection**

- **Determine the base material**
  - Identify the materials of the pipes and pressure vessels (e.g., carbon steel, stainless steel, alloy steel, aluminium, etc.).
  - Consider the application and the working conditions (temperature, pressure, and corrosiveness) of the system.

- Ensure that the material chosen complies with relevant standards (e.g., ASME Section VIII for pressure vessels).

Check material properties

- Mechanical properties: Consider yield strength, tensile strength, ductility, and toughness for selecting the base material.
- Corrosion resistance: In environments with chemical exposure, choose materials with corrosion-resistant properties (e.g., stainless steel for high corrosion resistance).
- Heat resistance: For high-temperature applications, materials like alloy steels (e.g., chromium-molybdenum) are recommended.

Select compatible filler material

- The filler material (electrode or wire) should be compatible with the base material to avoid welding defects and ensure strength.
- For example, use E7018 electrodes for mild steel or ER308 for stainless steel.

✓ **Identify the welding process**

Choose the appropriate welding process

- Shielded Metal Arc Welding (SMAW): Commonly used for structural steel welding, including pipes and pressure vessels.
- Gas Tungsten Arc Welding (GTAW/TIG): Preferred for high-quality welds, especially in thin materials and critical joints (e.g., stainless steel).
- Gas Metal Arc Welding (GMAW/MIG): Used for faster welding, suitable for long, continuous welds on larger pipes or vessels.
- Flux-Cored Arc Welding (FCAW): Often used for heavy-walled pipes and vessels due to its deep penetration.

Ensure process compatibility with materials

- The welding process must be compatible with the material type and thickness. For example, TIG welding is often used for stainless steel and thin-walled pipes, while SMAW is better for thicker sections.

✓ **Selection of welding tools and equipment**

Welding machine:

- Choose a welding machine capable of the selected welding process (SMAW, GTAW, etc.).
- Ensure the machine has sufficient amperage and voltage for the material thickness and process.

Welding electrodes or filler wire

- Based on the material and process, select the appropriate electrodes or filler wire. For example:
- E7018 for carbon steel.
- ER70S-6 for mild steel in MIG welding.
- ER308 for stainless steel in TIG welding.

- **Electrode holder, TIG torch, or MIG gun**

Select appropriate accessories (e.g., electrode holder for SMAW or TIG torch for GTAW) based on the welding process.

- **Welding rod oven (for SMAW):**

To prevent moisture absorption by the electrodes, use a rod oven to store electrodes like E7018, which are sensitive to moisture.

- **Shielding gas (for TIG and MIG):**
  - Choose the appropriate shielding gas depending on the material:
  - Argon for TIG welding stainless steel and aluminium.
  - Carbon dioxide (CO2) or argon/CO2 mix for MIG welding mild steel.
- **Personal protective equipment (PPE)**
  - Welding helmet with auto-darkening feature.
  - Welding gloves, aprons, and sleeves made of fire-resistant materials.
  - Safety glasses and ear protection to shield against sparks and noise.

✓ **Selection of supporting tools and fixtures**

- **Pipe clamps and aligners**

Use specialized clamps and aligners to hold the pipes or pressure vessel components in place during welding.

- **Positioners and rotators**

For larger pipes or pressure vessels, use welding positioners and rotators to facilitate easier access to the welding joint.

- **Measuring and marking tools**

Use calipers, measuring tapes, and marking tools to ensure proper alignment and preparation of the weld area.

- **Beveling tools:**

Pipes and pressure vessels often require beveled edges for welding. Use mechanical or manual beveling tools to prepare the edges.

✓ **Pre-weld preparation and quality control**

- **Surface preparation**

Clean the surfaces to be welded to remove rust, oil, paint, or other contaminants that could affect the weld quality. Use wire brushes, grinders, or chemical cleaners if necessary.

Preheating (If required)

Preheat thicker materials or certain metals (e.g., cast iron, some steels) to reduce the risk of cracking. Use temperature indicators or infrared thermometers to ensure the correct preheating temperature.

Welding procedure specification (WPS)

Ensure you have a Welding Procedure Specification (WPS) that outlines the process parameters, materials, and techniques that should be followed to meet industry standards.

Testing and inspection tools

Post-weld testing tools such as ultrasonic testing (UT), radiographic testing (RT), or dye penetrant testing (DPT) to check for defects like cracks or porosity.

✓ **Post-welding procedures**

Post-weld heat treatment (PWHT)

For certain materials and thicknesses, post-weld heat treatment may be required to relieve residual stresses and improve the mechanical properties of the weld.

Surface finishing

Remove slag, spatter, or excess material using grinders, wire brushes, or chemical solutions.

Final inspection:

Conduct a thorough inspection of the weld for defects and ensure compliance with quality standards (e.g., ASME or API codes).

Practical Activity 1.3.3: Applying handling techniques as used in pipes and pressure vessels welding.

Task:

You are requested to go in manufacturing workshop and handle materials, tools and equipment by applying handling techniques as required for the work in pipes and pressure vessels welding based on handling criteria.

1: Apply safety precautions

3: Handle materials, tools and equipment required for the work.

5: Present your work to the trainer and whole class.

6: Read key reading 1.3.3 and ask clarification where necessary.

7: Perform the task provided in application of learning 1.3.

Key readings 1.3.3: Apply handling techniques as used in pipes and pressure vessels welding.

- **Manual handling**

Manual handling refers to the process of lifting, carrying, pushing, or pulling objects by hand or bodily force. It often involves tasks that require physical strength and coordination, making it essential to use proper techniques to prevent injuries.

Figure 52: Manual handling

✓ **Procedures for safe manual handling of tools, materials, equipment, and products**

Assess the load

- Determine the weight of the load.
- Evaluate if the load is bulky or awkward to handle.
- Identify where to grip the load securely.

Plan the lift

- Ensure the route is clear of obstacles.
- Wear gloves, steel-toed shoes, and other necessary protective equipment to enhance safety.
- Know where you are placing the load and make sure the area is safe.
- If the load is too heavy or awkward, enlist help and plan the lift.

Prepare your body

- Position yourself close to the load.

- Place your feet shoulder-width apart for balance.
- Squat down to lift, keeping your back straight.

Grip the load
- Use both hands to grip the load firmly.
- Ensure your fingers are clear of any pinch points.

Lift safely
- Lift with your legs, not your back. Straighten your legs while keeping the load close to your body.
- Maintain a neutral spine position.

Carry the load
- Hold the load close to your body to minimize strain.
- Avoid twisting your body; turn your whole body instead.
- If the load obstructs your view, walk backwards carefully.

Place the load
- Bend your knees to lower the load, keeping your back straight.
- Ensure the load is placed securely and safely.

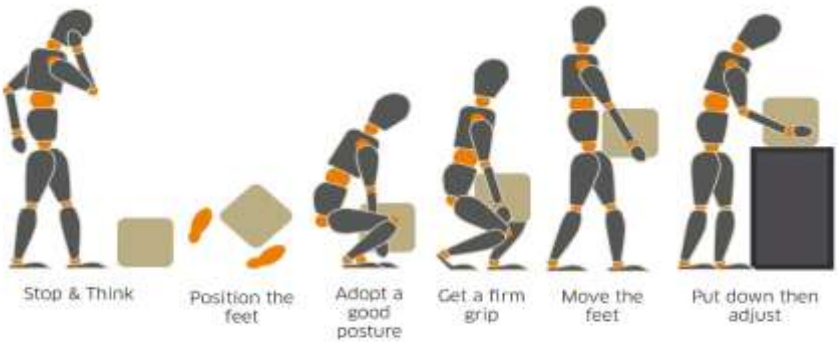


Figure 53: Procedures for safe manual handling

- **Mechanical handling**

Mechanical handling involves the use of equipment and machinery to move, lift, or transport objects. This method reduces the physical burden on workers and enhances efficiency.

✓ **Mechanical handling equipment**

Forklifts: Used for lifting and transporting heavy loads over short distances.


Figure 54: Forklifts

- **Cranes:** Ideal for lifting heavy and bulky items vertically and moving them horizontally.

Figure 55: Cranes

- **Pallet jacks**

Hand-operated devices for lifting and moving pallets.


Figure 56: Pallet jacks

- **Hoists**

Used for lifting heavy loads vertically, often in construction or manufacturing.

Figure 57: Hoists

✓ **Procedures for Mechanical Handling**

- **Equipment selection**
  - **Choose the right equipment:** Select appropriate mechanical handling equipment (e.g., forklifts, cranes) based on the load type and weight.
- **Inspection and Maintenance**
  - **Conduct pre-use inspections:** Check for any damage or maintenance needs on the equipment before use.
  - **Ensure proper functioning:** Verify that all controls, indicators, and safety features are operational.
- **Operator training**
  - **Ensure proper training:** Operators should be trained and certified to use the chosen equipment safely.
  - **Review safety procedures:** Reiterate safety protocols before operation.
- **Safe operation**
  - **Load management:** Ensure loads are within the equipment's capacity limits. Distribute loads evenly.
  - **Use proper signals:** Communicate using hand signals or radios when working with others during lifting operations.
  - **Be aware of surroundings:** Maintain awareness of your environment, including pedestrians and other equipment.
- **Post-use procedures**
  - **Secure equipment:** After use, park equipment in designated areas and engage safety features.
  - **Report issues:** Document and report any equipment faults or maintenance needs.

- **Conveying handling**

Conveying handling specifically refers to the transport of materials using conveyor systems. These systems are designed to move products or materials from one location to another, often within a facility.

- ✓ **Components of conveyor system**
- **Conveyor belt:** The surface that carries the load.
- **Drive unit:** Powers the conveyor, typically using electric motors.
- **Idlers:** Support the belt and help it maintain tension.
- **Control systems:** Manage the operation of the conveyor, including speed and direction.

Figure 58: conveyer system

- ✓ **Types of conveyors**
- **Belt conveyors:** Use a continuous belt to transport materials. Commonly used for bulk materials and packaged goods.
- **Roller conveyors:** Consist of parallel rollers that allow items to roll along the surface. Suitable for heavy and palletized loads.
- **Chain conveyors:** Utilize chains to move items, ideal for heavy-duty applications like automotive assembly.
- **Screw conveyors:** Use a rotating helical screw to move materials, often used for bulk solids.
- **Pneumatic conveyors:** Transport materials through air pressure, suitable for powders and lightweight materials.
- **Procedures for applying conveying handling**

- ✓ **System design and setup**
- **Plan the layout:** Design the conveyor system layout to optimize workflow and minimize hazards.
- **Install properly:** Ensure that the conveyor is installed according to manufacturer specifications and safety standards.

✓ **Loading procedures**

- **Manual loading:** When loading materials manually, follow safe manual handling techniques as outlined previously.
- **Automated loading:** If using automated systems, set up sensors and controls to ensure proper loading.

✓ **Operational guidelines**

- **Start-up procedures:** Before starting the conveyor, ensure all personnel are clear from the area.
- **Monitor operation:** Regularly observe the conveyor during operation to detect any issues or jams.

✓ **Safety measures**

- **Emergency stops:** Ensure that emergency stop buttons are easily accessible and functional.
- **Guarding:** Use safety guards to protect operators from moving parts and pinch points.

✓ **Maintenance and inspections**

- **Regular inspections**: Conduct routine checks on belts, rollers, and other components for wear and tear.
- **Document maintenance**: Keep records of maintenance activities and repairs.

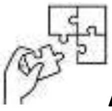
✓ **Post-operation procedures**

- **Shut down safely**: Follow proper procedures for shutting down the conveyor system after use.
- **Clean up**: Clear the area of any debris or materials that may have accumulated during operation.

Points to Remember

- Metal plates used in pressure vessels must meet stringent standards to ensure safety and performance under high-pressure conditions.
- The walls of the cylinder are thick to ensure they can safely contain the gas under high pressure.
- Selection of the right materials, tools, and equipment for welding pipes and pressure vessels, ensuring high-quality welds, efficiency, and safety.
- Implement regular training sessions focused on proper manual handling techniques.

- Ensure all operators are trained and certified in the safe operation of mechanical handling equipment.
- Implement a regular inspection schedule for conveyor systems to check for wear and tear, ensuring all components function correctly.



Application of learning 1.3.

There is a project of assembling stainless steel water tank, in your school manufacturing workshop but the hired welder is not skilled in selection of tools, materials and equipment. You are asked to select tools, materials and equipment required for the task:

Indicative content 1.4: Setting MIG/MAG, TIG and FCAW Equipment

Duration: 5 hrs

Theoretical Activity 1.4.1: Description of MIG/MAG, TIG and FCAW machine parameters

Tasks:

1: Answer the following questions:

i. What do you understand by the following MIG/MAG, TIG and FCAW welding machine parameters?

a. Gas pressure
b. Current
c. Voltage
d. Wire feed speed

2: Write the answer on flipchart/papers.

3: Present your findings to your classmates and trainer.

4: For more clarification, read the key readings 1.4.1. and ask questions where necessary.

Key readings 1.4.1.: Description of MIG/MAG, TIG and FCAW machine parameters

- **MIG/MAG (Metal Inert Gas / Metal Active Gas) welding parameters**

✓ **Wire Feed Speed (WFS)**

Wire Feed Speed (WFS) refers to the rate at which welding wire is fed into the weld pool during the MIG (Metal Inert Gas) or MAG (Metal Active Gas) welding processes. WFS is typically measured in meters per minute (m/min) or inches per minute (in/min).

- If the wire feed speed is too high, it can lead to a cold weld, insufficient penetration, or an unstable arc. This can result in poor weld fusion and weak joints.
- Conversely, a low wire feed speed may cause excessive heat build-up, leading to burn-through, excessive spatter, or a weak weld due to insufficient material being deposited.

- WFS is closely linked to voltage and travel speed. Increasing the wire feed speed usually requires a corresponding increase in voltage to maintain a stable arc and achieve good penetration.
- Different materials and thicknesses require different wire feed speeds. For example, thicker materials may need higher feed speeds to ensure adequate heat input and penetration.
- WFS settings are adjusted based on the specific welding application, including the type of material (e.g., mild steel, aluminium, stainless steel) and the specific joint configuration.

MIG/MAG Wire Feed Speed Chart

Material	Thickness (mm)	Wire Diameter (mm)	Wire Feed Speed (m/min)	Voltage (V)
Mild Steel	1.0	0.8	3.5 - 5.0	20 - 23
	3.0	0.8	5.5 - 7.5	23 - 25
	6.0	1.0	6.0 - 8.0	24 - 26
	10.0	1.2	7.0 - 9.0	25 - 28
Aluminium	1.0	0.8	4.0 - 5.0	22 - 24
	3.0	1.0	5.0 - 6.5	24 - 26
	6.0	1.2	6.5 - 8.0	25 - 27
Stainless Steel	1.0	0.8	3.0 - 4.5	19 - 21
	3.0	0.8	4.5 - 6.0	20 - 22
	6.0	1.0	5.5 - 7.0	22 - 24

✓ **Voltage in MIG/MAG Welding**

- The voltage setting on the welding machine determines the arc length and heat input. Higher voltage results in a longer arc and deeper penetration, while lower voltage provides a shorter arc and less penetration.
- For MIG welding: Voltage usually ranges from 18 to 30 volts, depending on the material thickness and welding position.
- For MAG welding: Voltage settings can vary similarly, often falling within the same range.
- **High voltage**: Increases heat, allowing for faster travel speeds but may lead to a wider bead and increased spatter.
- **Low voltage**: Provides better control over the bead profile and penetration but may require slower travel speeds.

- **Adjustment**: Voltage should be adjusted based on the wire feed speed and the type of material being welded to achieve optimal weld quality.
- **Material thickness**: Thicker materials generally require higher voltage.
- **Wire diameter**: Larger diameter wires often need higher voltage settings.
- **Shielding gas**: The choice of gas (inert or active) can also influence the required voltage settings.
- Maintaining the appropriate voltage is crucial for achieving strong and quality welds in both MIG and MAG processes.

MIG/MAG voltage chart

Wire Diameter (mm)	Material Thickness (mm)	Voltage Range (V)
0.8	0.5-2	16-20
1.0	1-4	18-24
1.2	3-6	20-26
1.6	5-10	24-30
2.0	8-12	26-32
2.4	10-20	28-34

✓ **Amperage**

- The amperage directly affects the amount of heat produced during welding. Higher amperage generates more heat, leading to deeper penetration into the workpiece, while lower amperage results in less heat and shallower penetration.

MIG/MAG amperage chart

Wire Diameter (mm)	Material Thickness (mm)	Amperage Range (A)
0.8	0.5-2	30-100
1.0	1-4	60 - 140
1.2	3-6	90 - 180
1.6	5-10	140 - 260
2.0	8-12	200 - 320
2.4	10-20	300 - 400

✓ **Shielding gas flow rate**

Protects the weld pool from atmospheric contamination. For MIG (inert gas like Argon), for MAG (active gas like CO_2).

- MIG Welding (with Argon or Argon/CO2 mix): Typically ranges from 10 to 25 litters per minute (L/min).
- MAG Welding (with CO2 or CO2/Argon mix): Usually set between 10 to 20 L/min for pure CO2 and slightly higher for gas mixtures.
- Vertical or overhead positions may require higher flow rates to ensure adequate coverage.
- Larger nozzles might need higher flow rates to effectively shield the weld area.
- If welding outdoors or in draft environments, increased flow rates can help counteract wind effects.
- Thicker materials or specific alloys may require adjustments to flow rates for optimal shielding.

MIG/MAG shielding gas flow rate chart

Wire Diameter (mm)	Shielding Gas Type	Recommended Flow Rate (L/min)
0.8	Argon	10 - 15
1.0	Argon	12 - 18
1.2	Argon	15 - 20
1.6	Argon	20 - 25
2.0	Argon/CO2 Mix (75/25)	15 - 20
2.4	CO2	12 - 18
2.4	Argon/CO2 Mix (80/20)	15 - 25

- **TIG (Tungsten Inert Gas) Welding Parameters**

✓ **Amperage:** Controls heat input and penetration. Adjusted with a foot pedal or machine controls.

✓ **Arc length (Voltage):** Determined by the gap between the tungsten electrode and the workpiece. Affects arc stability and bead width.

TIG Welding Voltage/Amperage Chart Based on Material Thickness and Electrode Type

Material thickness (inches)	Amperage range (DC)	Electrode type	Electrode diameter (inches)
0.020" (0.5 mm)	15-30 A	2% Thoriated, ceriated (Red, Grey)	1/16" (1.6 mm)
0.040" (1 mm)	30-50 A	2% Thoriated, Ceriated (Red, Grey)	1/16" (1.6 mm)

1/16" (1.6 mm)	50-80 A	2% Thoriated, Ceriated (Red, Grey)	1/16" or 3/32" (2.4 mm)
1/8" (3.2 mm)	80-120 A	2% Thoriated, Lanthanated (Red, Blue)	3/32" (2.4 mm)
1/4" (6.4 mm)	125-250 A	2% Thoriated, Lanthanated (Red, Blue)	3/32" or 1/8" (3.2 mm)
3/8" (9.5 mm)	200-350 A	2% Thoriated, Lanthanated (Red, Blue)	1/8" (3.2 mm)
1/2" (12.7 mm)	300-400 A	2% Thoriated, Lanthanated (Red, Blue)	1/8" or 5/32" (4.0 mm)

- ✓ **Gas flow rate:** Typically, Argon, protects the weld pool and tungsten. Flow rates depend on material and thickness.

TIG Welding Gas Flow Rate, Nozzle Size, Metal Thickness, and Voltage

Material thickness (inches)	Amperage range (DC)	Voltage range (V)	Nozzle size	Gas Flow rate (CFH)	Material type
0.020" (0.5 mm)	15-30 A	10-12 V	#4 (1/4")	10-15 CFH	Thin steel, stainless steel
0.040" (1 mm)	30-50 A	12-14 V	#4 or #5	12-17 CFH	Thin aluminum, steel
1/16" (1.6 mm)	50-80 A	13-15 V	#5 (5/16")	15-20 CFH	General aluminum, steel
1/8" (3.2 mm)	80-120 A	14-16 V	#6 (3/8")	15-20 CFH	General steel, stainless
1/4" (6.4 mm)	125-250 A	16-18 V	#6 or #7	17-22 CFH	Thicker steel, stainless

3/8" (9.5 mm)	200-350 A	18-20 V	#7 (7/16")	20-25 CFH	Thick aluminum, steel
1/2" (12.7 mm)	300-400 A	18-22 V	#8 (1/2")	25-30 CFH	Heavy-duty aluminum, steel

- **#6**: This is the nozzle size number.
- **(3/8")**: This indicates the nozzle's actual diameter, which is **3/8 of an inch** (approximately 9.5 mm).

- **FCAW (Flux-Cored Arc Welding) parameters**

- ✓ **Wire feed speed (WFS):** Controls the amount of weld metal deposited.
- ✓ **Voltage:** Affects arc length and penetration. Needs to be set according to the wire size and material.
- ✓ **Amperage:** Linked to WFS, higher amperage increases penetration.
- ✓ **Shielding gas flow rate (if used):** Some FCAW processes use additional gas, typically $CO2$ or a $CO2$/Argon mix.
- ✓ **Polarity:** Usually DCEP (Direct Current Electrode Positive) is used, though DCEN may be applied in certain situations.
- ✓ **Stick-out length:** The distance between the contact tip and the workpiece. A longer stick-out reduces current and can lower penetration.

FCAW Voltage, Amperage, Wire Feed Speed, and Shielding Gas Flow Rate Chart

Material thickness	Wire diameter	Amperage range (A)	Voltage range (V)	Wire feed speed (IPM)	Shielding gas flow rate (CFH)	Wire type
1/16" (1.6 mm)	0.030" (0.8 mm)	70-120 A	15-19 V	175-250 IPM	20-30 CFH (for gas-shielded)	Gas-shielded, Self-shielded
1/8" (3.2 mm)	0.035" (0.9 mm)	100-180 A	16-21 V	225-350 IPM	25-35 CFH (for gas-shielded)	Gas-shielded, Self-shielded
1/4" (6.4 mm)	0.035" (0.9 mm)	150-220 A	17-23 V	250-400 IPM	25-40 CFH (for gas-shielded)	Gas-shielded

3/8" (9.5 mm)	0.045" (1.2 mm)	200-300 A	23-28 V	250-500 IPM	30-40 CFH (for gas-shielded)	Gas-shielded
1/2" (12.7 mm)	0.045" (1.2 mm)	250-350 A	25-30 V	300-550 IPM	30-45 CFH (for gas-shielded)	Gas-shielded
5/8" (16 mm)	1/16" (1.6 mm)	250-400 A	26-32 V	200-350 IPM	35-50 CFH (for gas-shielded)	Gas-shielded

Practical Activity 1.4.2: Setting MIG/MAG, TIG and FCAW equipment

Task:

You are requested to go in manufacturing workshop and setting up MIG/MAG, TIG and FCAW welding machine as required for the work in pipes and pressure vessels welding based on selection criteria.

1: Apply safety precautions

2: set-up equipment as required for the work.

3: Present your work to the trainer and whole class.

4: Read key reading 1.4.2 and ask clarification where necessary.

5: Perform the task provided in application of learning 1.4.

Key readings 1.4.2: Setting MIG/MAG, TIG and FCAW equipment

- **Connecting welding machine component**

✓ **Setup TIG welding equipment.**

A basic knowledge of equipment setup, adjustment, and shutdown is necessary to make effective and efficient welds. This section will give you the basics of setup and electrode preparation.

- Always refer to the manufacturer’s safety precautions and proper tip preparation.
- Also, always wear your safety glasses when you are in the welding area.
- Attach the remote control to the remote-control outlet on the power source.

- Check torch cables and connect them to the power source.
- Select the appropriate electrode for the job.

✓ **Equipment's in TIG welding are described as under:**

- **Power source**

Constant current (cc) machines can produce AC or DC welding power; they can be rotating (generators), static (transformer/rectifier), or three phase inverter machines.

a) Generator and alternator welding machine: For shop use, an electric motor can power a generator welding machine, or an internal combustion engine (gasoline or diesel) can do it for field use. You can adjust generator welding machines intended for shielded metal arc welding to function for gas tungsten arc welding if you add an inert gas and a high frequency attachment. Generator welding machines can provide DC power, and in some cases both AC and DC power to the arc, depending on the machine design. You can also adapt alternator welding machines (also called rotating or revolving field machines) for gas tungsten arc welding. These machines consist of an electric generator made to produce AC power.

b) Transformer-rectifier welding machines: Transformer-rectifier welding machines are used much more widely for gas tungsten arc welding than motor-generator welding machines. Transformer-rectifier machines provide both AC and DC welding current to the arc. A single-phase transformer producing alternating current is connected to the rectifier, which then produces DC current for the arc. The rectifier is an electrical device which changes alternating current into direct current.

The transformer-rectifier welding machines are available in different sizes and have several advantages over rotating power sources:

− Lower operating costs

− Lower maintenance costs

− Quiet operation

− Lower power consumption while idling

− No rotating parts

Figure 59: Transformer-rectifier welding machines

c) Inverter power sources: A recently developed machine uses the inverter and different levels of programming. These machines operate on three-phase input power. The three-phase input helps overcome the line unbalance that occurs with the single-phase transformer-rectifier machines. Inverters provide power down to 0.5 ampere with a very fast response time of one millisecond and less than 1 % ripple. Different programming is available, depending on the complexity of the job. The high frequency inverters are very quiet and provide outstanding arc stability.

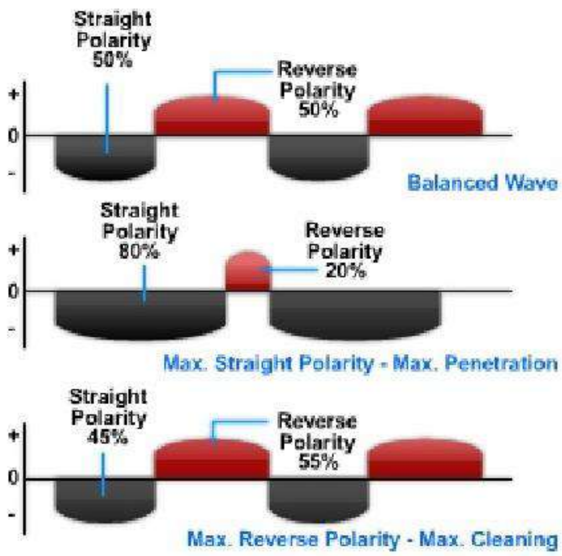
d) Transformer welding machines: Transformer welding machines are not used often for gas tungsten arc welding except at home shops or small job shops where gas tungsten arc welding is used only occasionally. Transformer welding machines produce AC power only and operate on single-phase input power. Like generator welding machines intended for SMAW, you can also adapt transformer welding machines for TIG by adding an inert gas and a high frequency attachment.

The transformer welding machine takes power directly from the line, transforms it to the power required for welding, and by means of various magnetic circuits, inductors, etc.

The main advantage of the transformer is that it has the lowest initial investment cost and uses electric power efficiently. However, movable parts tend to vibrate, wear, and become loose, which creates undesirable noise.

e) square wave power source

To overcome the arc extinguishing-restricting problem, a square wave AC output power source was developed. Either the conventional constant current type or the constant voltage type of power source can use the square wave output form.



TIG welding torch

It is a most important part of TIG welding. This torch has three main parts, tungsten electrode, collets and nozzle. This torch is either water cooled or air cooled. In this torch, collet is used to hold the tungsten electrode. These are available in varying diameter according to diameter of tungsten electrode. The nozzle allows the arc and shielded gases to flow into welding zone. The nozzle cross section is small which gives high intense arc. There are passes of shielded gases at nozzle. The nozzle of TIG needs to replace in regular interval because it wears out due to presence of intense spark.

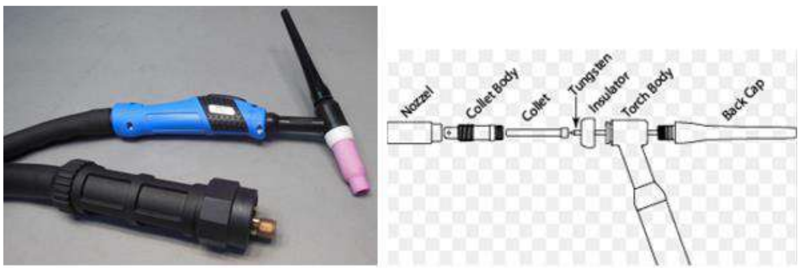


Figure 60: TIG welding torch

only for this process, are available in a variety of types and sizes. The torch conducts the welding current to the arc and the shielding gas to the arc area. It usually includes various cables, hoses, and adaptors for connecting the torch to the power, gas, and cooling supplies. Manual torches should also have a handle so the welder can manipulate the arc.

Shielding gas supply line (normally from a cylinder)

Normally argon or other inert gases are used as shielded gas. The main purpose of shielded gas to protects the weld from oxidization. Shielded gas does not allow coming oxygen or other air into welded zone. The selection of inert gas is depending upon metal to be welded. There is a system which regulates the flow of shielded gas into welded zone.

- **Foot control unit (common option)**

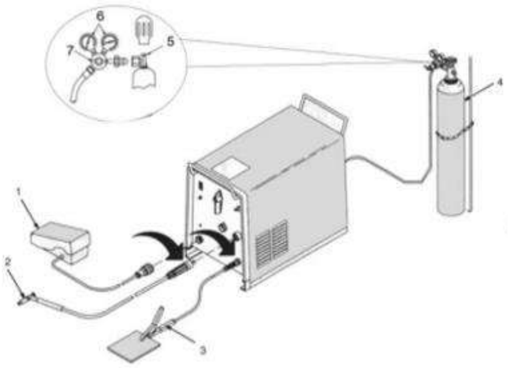


Figure 61: Foot control unit

	Parts	Function
1	Remote control	Controlling amperage for GTAW
2	Torch	Housing of tungsten electrode Connect receptacle as shown
3	Work clamp	Where the electron is flowing
4	Cylinder	Where compress necessary gas for welding. Use a chain to secure the cylinder to wall other stationary support.
5	Cylinder valve	Open valve slightly so gas blow dirt from valve, close valve
6	Regulator/Flow gauge	Install so face is vertical
7	Flow adjust	Typical flow rate is 20 cfh (cubic feet per hour)

The shielding gas is supplied to the regulator and flowmeter from either cylinder or a manifold system. The cooling water line in the shop or a circular pump system controlled by a pressure reducer.

- **Water Circulators:**

When you use a water-cooled torch, you must have a continuous water supply via a water circulator or directly from a hose connection to a water tap. Hoses, which may or may not go through a valve in the welding machine, carry the water to the welding torch.

Figure 62: Water Circulators

✓ **Procedures for assembling TIG welding equipment**

Hosepipe connection

The hose assembly carries the shielding gas, welding current cable and cooling water pipes from the composite power source to the welding torch. Cooling water is needed where a high current is used e.g., 80% continuous operation with current operation over 250 amps. The hose assembly carries an additional cable from the torch control switch back to the power source, which allows the gas, water flow, welding current and high (HF) supply to be controlled from the torch.

Cable connection

The welding cables and connectors connect the power source to the torch and to the work, essentially the same as those used for SMAW. The cables are normally made of copper or aluminum and consist of hundreds of fine wires enclosed in an insulated casing of natural or synthetic rubber. The cable connecting the work to the power source is the work lead, which typically connects to the work by pincher, clamps, bolt, or special connection. The cable connecting the torch to the power source is the electrode lead, and it is part of the torch assembly.

Assembling of welding torch

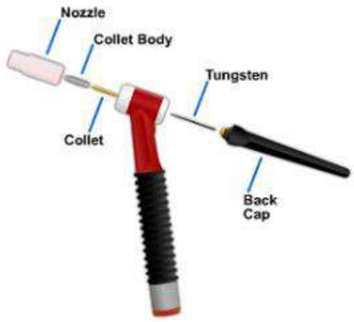
Various types of welding torch are available for TIG welding. They may be air-cooled or water-cooled and are usually fitted to the hose assembly. A remote-control switch is fitted on some torches.

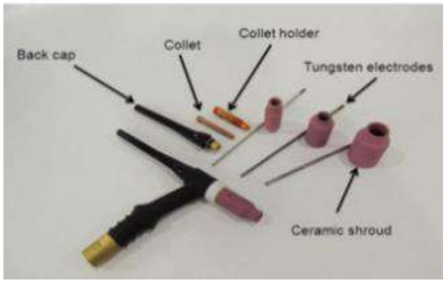
- The air-cooled torches are cooled by the flow of the shielding gas (which means that they really are gas-cooled). The only air cooling occurs from the heat radiating into the atmosphere.

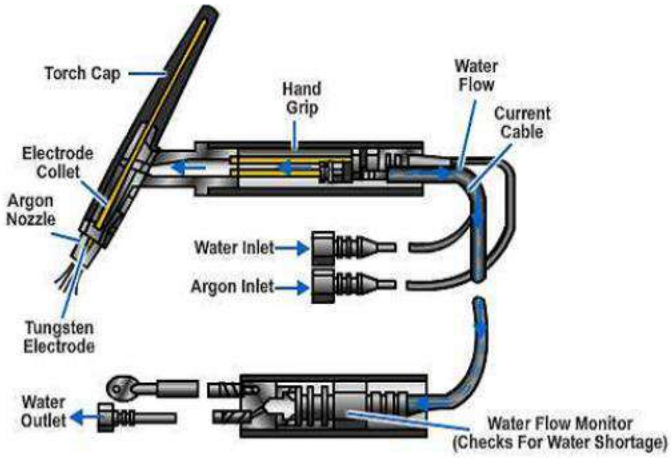
- Water-cooled torches have water circulating through the torch, which accounts for most of the cooling; the shielding gas does the rest.

The procedures of assembling welding torch are followed as follow

- Thread the collet body into the torch head.
- Insert the collet into the collet body.
- Install the nozzle.
- Insert the electrode so the tip extends about 1/2 inch beyond the nozzle.
- Screw the cap into the back of the torch head and tighten it lightly so the electrode will move with finger pressure.
- Adjust the electrode stick out and tighten the cap to secure the electrode in place.
- Place the torch on its hanger so it will not arc when you turn the power switch on.
- Do not lay it across the welding table







Cross-section of water coller TIG welding torch

Figure 63: welding torch parts

Fixing of flow meter

Flowmeter is back pressure compensated help to ensure accurate readings when line restrictions are present. Simple to operate and convenient to use. Long service life with 2-inch pressure gauge design. Perfect for MIG and TIG welding. Brass Body. The output flow is adjustable from 10 to 60 **cfh** (cubic feet per hour), and is indicated by a ball which moves up and down in the flow tube. regulators are mainly classified into 3 categories:

- Argon regulator
- CO2 regulator
- Argon & CO2 regulator
- Helium regulator

Figure 64: Difference flowmeter

- **Argon CO2 Gas MIG and TIG Flow meter control (Welding weld regulator gauge:** it is combination of regulator and flow meter as one unit. Designed for MIG TIG applications and provide accurate regulator of gas flow. With clear scale for easy reading the data. The data is so accurate, long service life and super durable. High technology and exquisite workmanship.

Figure 65: Argon CO2 Gas MIG and TIG Flow meter

Fixing the foot pedal (optional)

This is a short work that deals with adding simple potentiometer-driven foot pedal current control to a TIG welder which is missing the appropriate connector, but has the necessary connections on the front panel PCB (Printed Circuit Board) in the housing. The foot pedal gives you the opportunity to regulate the welding current during welding. When fixing it:

- Open the cover to the wire spool. A multi-pin terminal is located beneath the wire feed rollers.
- Plug the pedal into this terminal. It's a pain but you must fully turn the collar of the plug tightly to make sure full contact is made in this terminal.

Figure 66: Foot pedal

✓ **Setup MIG/MAG welding equipment**

Procedures for assembling MIG/MAG welding equipment.

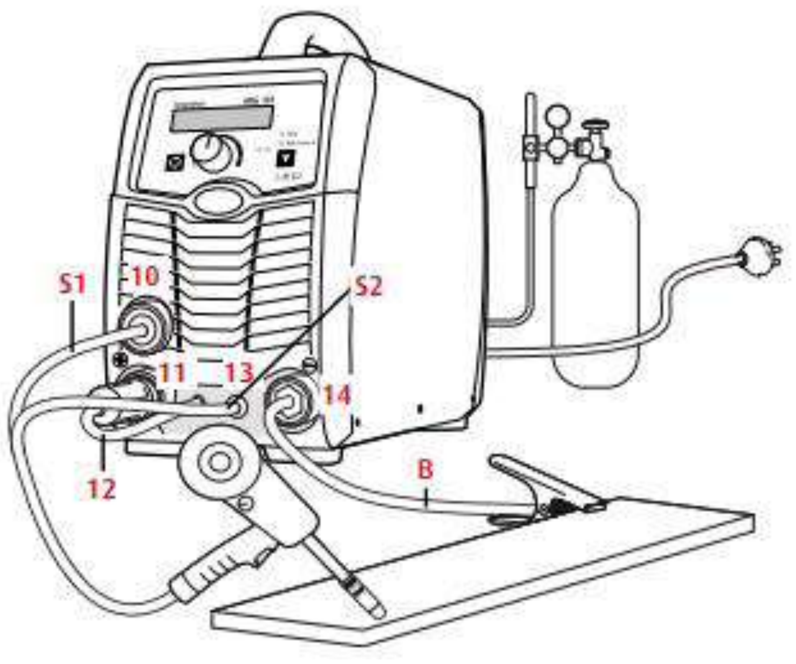


Figure 67: Setup MIG/MAG welding equipment

- Connect the gas cylinder to the regulator. Select correct shielding gas for the application.
- Plug S1 spool gun euro connection into 10-euro output connection.
- Plug S2 spool gun control cable into 13 control connection.
- Fit wire spool to the spool gun - Lift cover up - Remove retaining screw by turning clockwise. - Slide mini spool in - Adjust spool tension using knurled ring on the spool shaft - Feed wire through front of the torch - Close cover

- Select the correct polarity for the type of wire used as indicated on the consumable packaging. This is achieved by swapping the polarity terminal wires. For most solid wires the terminal should be set as torch positive.
- For torch positive, plug the 12 short mechanical connectors (link plug) on the front panel into the 11 positive (+) terminal and the B work return lead into the 14 negative (-) terminal.
- For torch negative, plug the 12 short mechanical connectors (link plug) into the 14 negative (-) terminal, and the B work return lead into the 11 positive (+) terminal.
- Turn machine on.
- The 4 Spool gun indicator light will illuminate. (Please note MIG Pulse Al function is not available with the spool gun).
- Please note wire feed speed is only active from the spool gun. 11 The MIG spool gun only takes the 100mm mini spool of wire.

Control unit

There are several control units like argon gas switch control, wire feeder control and arc self-control in control unit.

Power source

In order to obtain a stable arc, the power source used for MIG/MAG welding must have a properly set or adjustable characteristic and an outlet for the appropriate inductance values. The static characteristic is the curve for voltage (V) versus current (A). A normal power source has a falling static characteristic, while a power source with an approximate flat characteristic is usually used for MIG/MAG welding.

If the welding result is to be good, the arc length should very as little as possible. When in MIG/MAG welding the wire is feeded with a constant speed, it is rather simple to obtain the right welding conditions by means of a power source of the constant voltage type. If the arc length is shorter than the set value, that is if the arc voltage lowered, is current intensity will automatically increase dramatically and the wire will melt quicker than it is feeder

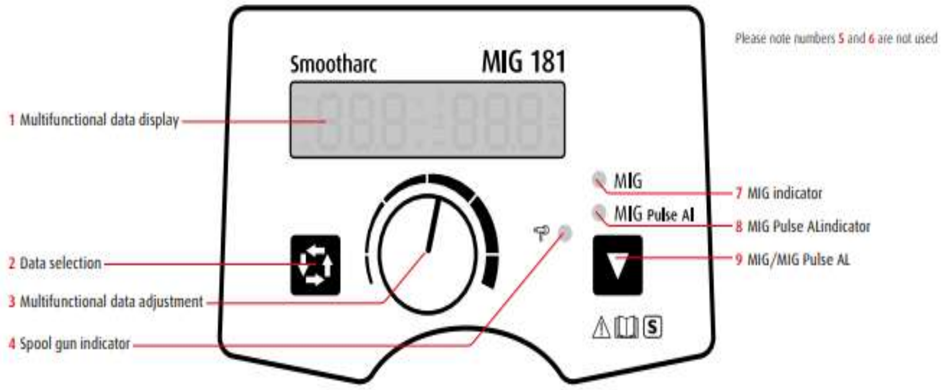


Figure 68: Power source control

Wire feed unit

The wire feed speed is connected with the control of the wire feeding that is with the control system. For the actual mechanical feeding there are three different systems in principle. The wire feed unit takes the filler wire from a spool, and feeds it through the welding torch, to the arc at a predetermined and accurately controlled speed. Normally, special knurled feed rolls are used with flux cored wires to assist feeding and to prevent crushing the consumable. Wire feeder is the most important part of inert gas metal arc welding equipment which has push type, pull type and pull-push type.

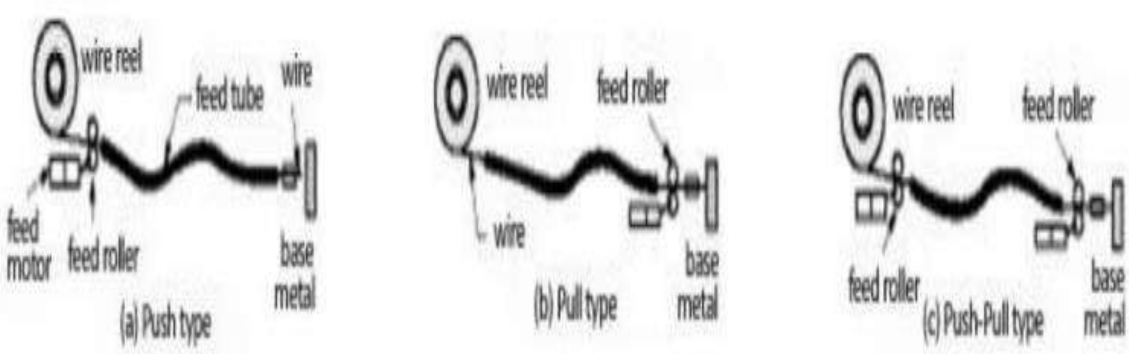


Figure 69: Wire feed unit

- **Push type:** The wire is pushed forward by the wire drive unit through the wire guide liner to the torch.

Figure 70: Wire feed unit push type

- **Pull type:** The wire is pulled forward to the torch by a wire feed unit in the torch, figure A, Both the wire feed unit and the wire rolls are placed inside the welding torch (segmented).

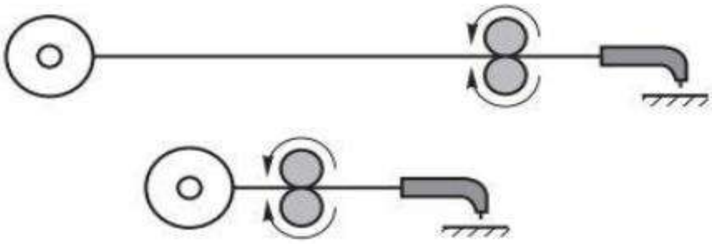


Figure A

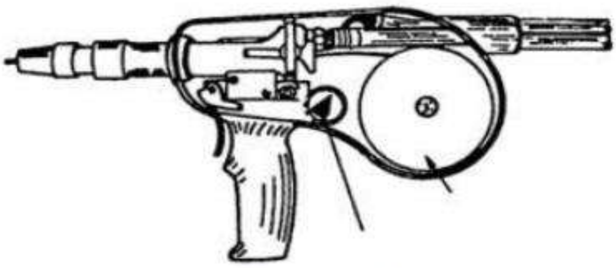


Figure B

Figure 71: Wire feed unit pull type

- **Pull- push:** The wire is pushed forward by a wire feed unit in the welding machine and at the same time it is pulled through the wire liner by a wire feed unit in the welding torch, the so-called push-pull system.

Figure 72: Wire feed unit push-pull type

Welding gun

The welding gun the welding gun is one of the most critical parts of the system. In addition to directing the wire to the joint the welding gun fulfils two important functions. It transfers the welding current to the wire via the contact tip and the shield nozzle directs the shield gas around the arc and weld pool. There are two types of welding guns' air/gas cooled and water cooled.

- **Air Cooled:** The air-cooled guns utilize the shielding gas passing through the body to cool the nozzle and have a limited current-carrying capacity. They are suited for light duty work. Some air-cooled guns are available with current ratings up to 500A but these are often heavy and not suited to extended work periods.

Figure 73: Air Cooled gun

- **Water Cooled:** The water-cooled guns are preferred for high current levels and especially at high duty cycles. They are much lighter in weight due to the lesser amounts of copper made possible by the cooling system.

Figure 74: Water Cooled gun

✓ **Setup FCAW welding equipment**

Procedures for assembling the FCAW welding equipment

When setting up the FCAW station, look for all potential safety problems. Spatter from FCAW can cause a fire. All flammable materials must be removed from the welding area Figure 2.27. illustrates a complete FCAW outfit Equipment. The same equipment may be used for flux cored arc welding. Remember, self-shielding FCAW does not require any shielding gas.

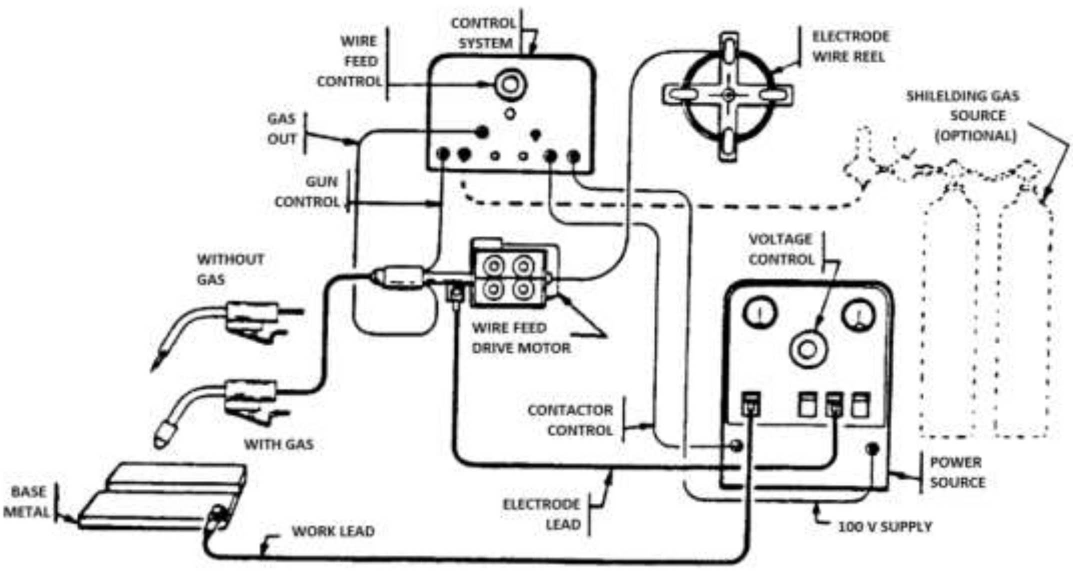


Figure 75: Setup FCAW welding equipment

Setting up a FCAW power source

In order to produce acceptable welds, a FCAW power supply must be properly adjusted for the material being joined and the desired metal transfer method. Before setting up the power source, the following information needs to be known:

- The type of base metal to be welded.
- Base metal thickness.
- The type of transfer method to be used.
- The type of shielding gas to be used.
- The type and diameter of welding wire.

Once this information is known, the welding machine can be properly set up. Only a few controls must be set prior to welding. First, adjust the voltage setting. The voltage determines the arc length and helps determine the metal transfer method.
Second, adjust the wire feed speed. Welding machines with a wire feeder built in have the wire feed speed control on the machine itself. If the wire feeder is a separate unit, the wire feed speed adjustment is on the wire feeder. When the welder adjusts the wire feed speed, he or she is also adjusting the machine's nominal amperage.

Steps of preparing a FCAW outfit for welding

- Connect a separate wire feed unit to the welding power source, if required. The manufacturer's instructions should be followed to make these connections. Usually, a single cable assembly is enough to electrically connect the wire feeder to the welding machine. The welding lead from the positive terminal of the welding machine is usually connected to the wire feeder. Connecting the positive lead to the wire feeder provides DCEP current.
- Mount the desired welding wire reel (spool) onto the wire feeder.
- Determine what shielding gas is required. No shielding gas is required for self-shielded FCAW. Properly secure the cylinder (if used) to prevent it from being knocked over. Check that the regulator and gas flowmeter are attached properly. Connect a hose from the flowmeter to the welding machine or wire feeder as required. The FCAW gas shielded processes require a shielding gas connection. The FCAW–Self shielded process does not. Finally, the hose and fittings should be checked to make sure there are no leaks in them.
- Connect the welding gun to the correct place on the welding machine or wire feeder. Quite often, two connections need to be made. One is the main cable that is connected where the welding wire exits the wire feeder. Attach this part of the cable assembly to its proper place. The second connection is for the electrical contact to the gun trigger. This part of the cable assembly also must be connected to its proper

place. A water-cooled gun has additional connections.

- Connect the workpiece led to the welding machine. Both the welding gun cable assembly and the workpiece lead should be checked for any signs of wear or cuts. Wear or cuts on the outside of these items may indicate damage to the leads.
- The workpiece clamp should be checked. The clamp should be clean so it can make a good electrical connection.
- If a water cooler is used, connect it to the welding machine or to the gun according to the manufacturers' recommendations. Usually, the welding machine, wire feeder, or welding gun is connected to the outlet on the water cooler. This way, cool water flows from the cooler to the gun. Warm water returning from the gun is connected to the inlet on the water cooler.

Techniques of insertion of core wire

To install electrode wire on a welding machine, follow these steps:

- Secure large-diameter flux-cored wires with four bands to prevent unwinding. Cut the wire between the coil and feeder, then loosen hold-down brackets to remove the coil.
- Remove the wire feed rollers from the feeder before mounting the new coil. Advance the feeder until the cutoff wire end is released and remove it with pliers.
- Clean or replace the liner each time a coil or spool is changed. Use compressed air to purge contaminants after removing the liner from the gun.
- Examine the contact tube and nozzle for wear, replacing them, if necessary, before adding a new coil.
- Insert the electrode through the feeder guides, manually advance the wire, replace the feed rolls, and remove the securing bands.
- Some wires require preheating for flux decomposition, with a recommended stick-out length of 2.5 inches. Gas-shielded wires need a nozzle with a stick-out of 0.75 to 1.5 inches.
- Use air or water cooling for the welding gun based on current levels; water cooling is essential for currents over 500 amps.
- A smoke exhaust system may be necessary due to high smoke levels from the process.
- Attach heat shields for high current densities and maintain the gun by cleaning spatter and dirt from the nozzle.
- Match feed rollers to wire size to prevent flattening. Use knurled V-groove rollers for large diameters, groove geared rolls for medium, and concave smooth rollers for small diameters. Most setups use pairs of rollers to push wire from feeder to gun.

- **Adjusting welding machine parameters**

The following basic MIG welding settings are for welding steel with solid wire. Joint design, position and other factors affect results and settings. When good results are achieved, record the parameters. Material thickness determines amperage**.** As a guideline, each .001 inch of material thickness requires 1 amp of output: .125 inch = 125 amps.

Select proper wire size according to amperage. Since you don't want to change wire, select one for your most commonly used thicknesses.

- 30-130 amps: .023 inch
- 40-145 amps: .030 inch
- 50-180 amps: .035 inch
- 75-250 amps: .045 inch

Set the voltage. Voltage determines height and width of the bead. If no chart, manual or specifications are available for setting the correct voltage, you can try this: While one-person welds on scrap metal, an assistant turns down the voltage until the arc starts stubbing into the workpiece. Then, start welding again and have an assistant increase the voltage until the arc becomes unstable and sloppy. A voltage midway between these two points provides a good starting point.

There is a relationship between arc voltage and arc length. A short arc decreases voltage and yields a narrow, ropey bead. On the other hand, a longer arc (more voltage) produces a flatter, wider bead. Too much arc length also introduces the possibility of undercut.

Set the wire feed speed. Wire speed controls amperage as well as the amount of weld penetration. A speed that's too high can lead to burn-through. If a manual or weld specification sheet is not available, use the multipliers in the following chart to find a good starting point for wire feed speed. For example, for .030-inch wire, multiply by 2 inches per amp to find the wire feed speed in inches per minute (ipm).

For wire size	**Multiply by**	**Ex. using 1/8 inch (125 amps)**
.023 inch	3.5 inches per amp	3.5 x 125 = 437.5 ipm
.030 inch	2 inches per amp	2 x 125 = 250 ipm
.035 inch	1.6 inches per amp	1.6 x 125 = 200 ipm
.045 inch	1 inch per amp	1 x 125 = 125 ipm

✓ **Selecting appropriate welding parameters**

Before MIG welding, it is necessary to select appropriate welding parameters based on welding conditions such as plate thickness, welding position, material, etc. These parameters, including welding current, voltage, wire feed speed, gas flow rate, etc., interact with each other and need to be comprehensively considered and balanced.

Generally, the following principles can be followed:

1. **Welding current:** It mainly affects the penetration depth of the weld seam, that is, the welding penetration force. The greater the current, the greater the penetration depth; conversely, the smaller the penetration depth. If the current is too high, it is easy to cause burn-through or spatter; if the current is too low, it is easy to cause a lack of fusion or porosity. Therefore, a suitable current should be selected according to the plate thickness and wire feed speed.
2. **Welding voltage:** It mainly affects the arc length and bead width, that is, the shape of the weld seam. The higher the voltage, the longer the arc length and the wider the bead width; conversely, the shorter the arc length and the narrower the bead width. If the voltage is too high, it is easy to cause spatter or porosity; if the voltage is too low, it is easy to cause wire sticking or deformation. Therefore, a suitable voltage should be selected according to the wire feed speed and material.
3. **Wire feed speed:** It mainly affects the amount of filler wire fed into the weld pool, that is, the heat input of welding. The faster the wire feed speed, the more filler wire is fed into the weld pool, and the greater the heat input; conversely, the slower the wire feed speed, the less filler wire is fed, and the smaller the heat input. If the wire feed speed is too fast, it is easy to cause build up or spatter; if the wire feed speed is too slow, it is easy to cause discontinuity or fracture. Therefore, a suitable wire feed speed should be selected according to the plate thickness and material.
4. **Gas flow rate:** It mainly affects the stability of the shielding gas around the arc, that is, the stability of the welding process. The greater the gas flow rate, the more stable the shielding gas, and the more stable the welding process; conversely, the less stable the shielding gas, and the less stable the welding process. If the gas flow rate is too high, it is easy to cause gas waste or nozzle blockage; if the gas flow rate is too low, it is easy to cause oxidation or porosity. Therefore, a suitable gas flow rate should be selected according to the arc length and ambient wind speed.

✓ **Methods for adjusting welding current and voltage**

After selecting appropriate welding parameters, you can start adjusting the current and voltage. There are many methods for adjusting current and voltage, here are two commonly used methods:

1) **Formula method:** Calculate the theoretical values of current and voltage based on certain formulas, and then adjust according to these values. This method is relatively simple and suitable for beginners. The following two formulas are commonly used:

- When welding current is less than 300A, the welding voltage can be calculated using the following formula:

U=（0.05I+14）±2V, Where U is the welding voltage, I am the welding current.

- When welding current is greater than 300A, the welding voltage can be calculated using the following formula:

U=（0.05I+16）±2V, Where U is the welding voltage, “I” is the welding current. For example: If the selected welding current is 200A, then according to the first formula, the welding voltage can be calculated as:

U=（0.05×200+14）±2V

U=（10+14）±2V

U=24±2V

In other words, the welding voltage should be between 22V and 26V.

2) Observation method: Judge whether the current and voltage are appropriate based on the phenomena such as sound, sparks, and droplets during the welding process, and then make fine adjustments. This method is more flexible and suitable for experienced individuals. **The following are some commonly used observation standards:**

1. If there are always droplet-shaped metal balls at the end of the wire and the frequency of excess is low, it indicates that the welding voltage is too high. In this case, the wire feed speed should be increased or the welding voltage should be decreased.
2. If the wire extension is slightly short and welding can be done normally, but wire sticking occurs when it is slightly longer, it indicates that the welding voltage is too low. In this case, the wire feed speed should be reduced or the welding voltage should be increased.
3. If the weld surface is smooth and free of spatter and porosity, and the sound is stable and crisp, it indicates that the welding current and voltage are appropriately matched. While there are some similarities in setting parameters for MIG/MAG, TIG, and FCAW (Flux-Cored Arc Welding) machines, each welding process has unique requirements. Here’s a breakdown of the parameters and considerations for each type:

1. MIG/MAG (Metal Inert Gas / Metal Active Gas)
   - **Gas Pressure**: **MIG**: Typically, argon or a mix of argon and CO2; set between 10-20 CFH. **MAG**: Generally, uses CO2 or an argon/CO2 mix; similar pressure range.
   - **Current**: Adjust according to material thickness; typical range is 60-300 amps.
   - **Voltage**: Set based on the thickness and type of material; usually between 18-30 volts.
   - **Wire Feed Speed**: Adjust to match current and voltage; common range is 100-700 inches per minute.

2. TIG (Tungsten Inert Gas)
   - **Gas Pressure**: Usually argon; set around 15-25 CFH, depending on the application.
   - **Current**: Set according to material thickness; can vary widely (typically 10-

300 amps). Use lower currents for thin materials.

- **Voltage**: Not as critical as in MIG; often inferred from the current setting. Adjust based on the arc length.
- **Filler Material Feed Speed**: Manual feeding; controlled by the welder. Adjust based on the weld pool size and needed deposition rate.

3. FCAW (Flux-Cored Arc Welding)

- **Gas Pressure**: If using external shielding gas, similar settings to MIG (10-20 CFH for argon/CO2 mix). Self-shielded FCAW does not require external gas.
- **Current**: Similar to MIG; adjusted based on material thickness. Common range is 60-300 amps.
- **Voltage**: Set according to the material and desired penetration; typical range is 18-30 volts.
- **Wire Feed Speed**: Adjust to match current and voltage; generally similar to MIG settings (100-700 inches per minute).

- **Procedures for testing welding machine functionality**

✓ **Visual inspection**

Check for damage

- Inspect the welding machine for any visible signs of damage, such as dents, cracks, or loose parts.
- Ensure all covers and safety guards are in place.

Inspect cables and connections:

- Examine the welding cables for fraying, cuts, or other wear.
- Check all connections, including the electrode holder and ground clamp, to ensure they are secure and free from corrosion.

Verify accessories:

- Ensure that all necessary accessories (torches, nozzles, etc.) are available and in good condition.

✓ **Power supply**

Check power source:

- Verify that the welding machine is connected to the appropriate power supply as specified in the operator's manual.
- Ensure that the circuit breaker or fuse is functioning and properly rated for the machine.

Turn on the machine:

- Power on the welding machine and listen for any unusual sounds that may indicate internal issues.

Read display indicators:

- If applicable, check the machine's digital display or indicators for proper functioning and error messages.

✓ **Electrode and ground connection**

- **Check electrode holder:**

– Ensure the electrode holder is securely connected and that the electrode is properly inserted and tightened.

- **Inspect ground connection:**

– Verify that the ground clamp is clean and securely connected to the workpiece or welding table.
– Ensure there is good electrical contact to minimize resistance.

✓ **Selection of welding parameters**

- **Set parameters:**

Adjust the welding machine settings according to the material type, thickness, and welding process being used:

– **Current:** Set based on material thickness.
– **Voltage:** Adjust according to the desired arc characteristics.
– **Wire feed speed (for MIG/FCAW):** Set according to the material and desired deposition rate.

- **Gas flow (for MIG/TIG):**

– If applicable, adjust the gas flow rate to the recommended settings (typically between 10-20 CFH).

✓ **Testing the weld**

- **Perform a test weld:**

– Select a scrap piece of material similar to the one intended for the actual work.
– Execute a test weld, ensuring to use the same parameters set previously.

- **Evaluate the weld quality:**

– Inspect the test weld visually for defects such as porosity, undercut, and proper bead shape.
– Check for consistent arc stability and appropriate penetration.

- **Conduct non-destructive testing (if required):**

– Depending on the application, perform non-destructive tests (e.g., ultrasonic testing, dye penetrant testing) to check for internal defects.

- **Document results:**

– Record findings, including any adjustments made to the parameters and the results of the test weld for future reference.

Points to Remember

- Each of setting-up processes requires fine-tuning based on material type, thickness, and position.
- The setting up procedures should be ordered step by step in order to avoid accident.
- Wearing PPE while setting up any equipment is mandatory for safety.

Application of learning 1.4.

In your school manufacturing workshop, there are MIG/MAG, TIG and FCAW equipment to be set for using them in assembling stainless steel cylindrical water tank of $1000m^3$ but the welder is not skilled for setting the mentioned equipment. You are asked to set the MIG/MAG, TIG and FCAW equipment as required for the task.

Learning outcome 1 end assessment

Written assessment

Q1. Read the following statement concerning pipes and pressure vessels welding description and answer by **TRUE** if it is correct or **FALSE** if it is incorrect.

a) Pressure vessels are containers designed to handle the same pressure as the surrounding environment.

b) TIG welding uses a non-consumable tungsten electrode and an inert gas for shielding.

c) One disadvantage of MIG/MAG welding is its sensitivity to wind and drafts, which can disrupt the shielding gas.

d) FCAW requires external shielding gas to protect the weld pool from contamination.

e) Job hazard analysis involves identifying hazards in each step of a job task and determining appropriate controls.

f) The use of automatic shutoff valves in pressure vessels is an example of an administrative control.

Q2**.** Read the following statements and choose by underling the letter corresponding to the correct answer

i.What is one advantage of welding in pipe and pressure vessel applications?

a. High sensitivity to wind
b. Cost-effectiveness
c. Requires low skill
d. Limited material versatility

ii.Which welding method uses a continuous wire electrode and can use either inert or active gases as shielding gas?

a. TIG
b. FCAW
c. MIG/MAG
d. SMAW

iii.Which of the following gases is used as a shielding gas in MIG welding?

a. Oxygen
b. Argon
c. Carbon Dioxide
d. Nitrogen

iv.Which of the following is an example of an engineering control for welding hazards?

a. Using a less toxic welding gas
b. Installing ventilation systems
c. Wearing flame-resistant gloves
d. Providing safety training

v. Which of the following is the first step in the 5S principle?

a. Set in Order
b. Shine
c. Sort
d. Sustain

Q3. Table below contain job hazard and types of hazards, match column A of job hazards to hazards types column B and provide the answer in provided space.

Answer	A	B
a)…..	a. Heavy pipe handling	1. Chemical hazard
b)…..	b. Welding in confined spaces	2. Explosion/fire hazard
c)…..	c. Welding near flammable materials	3. Radiation exposure
d)…. .	d. Arc welding without a helmet	4. Confined space hazard
e)……	e. Welding toxic fumes	5. Mechanical hazard
		6. Physical hazard

Q4. Read the following sentence and complete the blank space with (gas, aluminium, zinc, liquid, chromium, argon, helium)

a. Pipes are cylindrical tubes used to transport ___ or ___ from one location to another.
b. Galvanized pipes are coated with ___ to protect them from corrosion.
c. Stainless steel pipes contain a small percentage of ___ to enhance corrosion resistance.
d. The gas commonly used in TIG welding and MIG welding for aluminium is ___.

Practical assessment

AB is a metal product assembling company located in MUSANZE district. They have received a tender of fabricating fuel pressure vessel of 100m^3 made in stainless steel with inlet and out let pipes, but there is no specialized worker for pipes and pressure vessels welding. Due to the reason described, you are requested to:

1. Apply 5S required for fabricating fuel pressure vessel
2. Select materials, tools and equipment required for fabricating fuel pressure vessel
3. Set-up MIG/MAG, TIG and FCAW equipment as required for fabricating fuel pressure vessel

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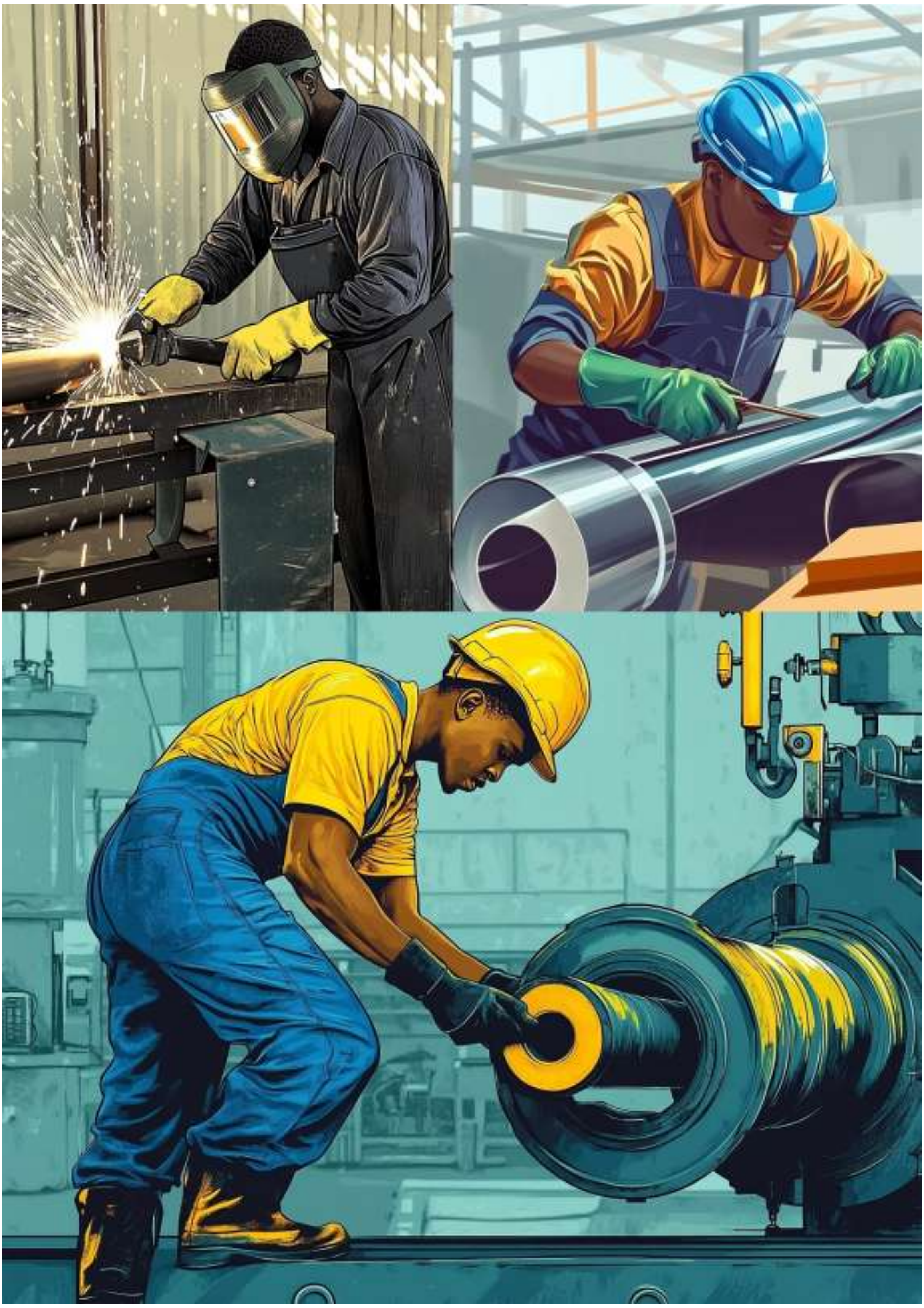


Indicative contents
2.1 Cutting the workpiece **2.2 Preparing edge of the workpiece** **2.3 Forming the workpiece**

Key Competencies for Learning Outcome 2: Prepare the Work Piece

Knowledge	Skills	Attitudes
• Identification of measuring techniques • Identification marking techniques. • Identification of cutting techniques. • Description of bending techniques • Description of rolling techniques	• Applying measuring techniques • Applying marking techniques • Positioning workpiece • Applying cutting techniques • Applying edge preparation techniques • Applying edge finishing methods • Applying bending techniques • Applying rolling techniques	• Being accurate in measuring workpiece • Being attentive when marking the workpiece • Being critical thinker while positioning the workpiece • Having precision when cutting the workpiece • Being carefully while preparing edge of workpiece • Being attentive in forming the workpiece

Duration: 30 hrs

Learning outcome 2 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify effectively the measuring techniques as used in pipes and pressure vessels welding
2. Apply properly measuring techniques as used in pipes and pressure vessels welding
3. Identify appropriately the marking techniques as used in in pipes and pressure vessels welding
4. Apply clearly marking techniques as used in pipes and pressure vessels welding
5. Position properly the workpiece as required in pipes and pressure vessels welding
6. Identify properly the cutting techniques as used in in pipes and pressure vessels welding
7. Apply effectively cutting techniques as used in pipes and pressure vessels welding
8. Apply correctly edge preparation techniques in pipes and pressure vessels welding
9. Apply properly finishing methods of edge in pipes and pressure vessels
10. Describe clearly the bending techniques used in pipes and pressure vessels welding
11. Apply effectively bending techniques used in pipes and pressures vessels
12. Describe clearly the rolling techniques used in pipes and pressure vessels welding
13. Apply correctly rolling techniques as used in pipes and pressure vessels

Resources

Equipment	**Tools**	**Materials**
● Gas cylinder ● Oxyacetylene kit ● Air compressor ● Band saw ● Pipe cutting machine	● Rulers ● Callipers ● Micrometres ● Tape measures ● Protractors	● Pipes ● Sheet metal ● Plate metal ● Shielding gas ● Papers

• Shearing machine • Laser cutting machine • Plasma cutting machine • Abrasive waterjet cutting machine • Angle grinder • Cut off machine • Bending machine • Rolling machine • Fume extractor • Drilling machine • PPE (welding gloves, welding helmet, safety boot, over all, safety glass, Face shield)	• Scribes • Marking gauges • Clamps • Vices • Hammers • Screwdrivers • Pliers • Wrenches • Saws • Drill bit • Shears • Brush • Roller	• Fuel • Discs • Filler metal

Indicative content 2.1: Cutting the Workpiece

Duration: 10 hrs

Practical Activity 2.1.1: Cutting the workpiece

Task:

You are requested to go in manufacturing workshop and cut workpieces required for pipes and pressure vessels welding based on cutting techniques.

1: Apply safety precautions

2: Cut the workpieces as required for the work.

3: Present your work to the trainer and whole class.

4: Read key reading 2.1.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 2.1.

Key readings 2.1.1: Cutting the workpiece

- **Applying measuring techniques**
  - ✓ **Pipe length measurement**

- **Tools:** Tape measure, laser measuring devices.
- **How to apply:** Measure the pipe length accurately by positioning the tape measure from one end to the other. Double-check measurements to ensure consistency, particularly when cutting pipes to specific lengths. For long pipes, use laser measuring devices for more precision and speed.

  - ✓ **Diameter measurement**

- **Tools:** Vernier calipers, Pi tapes, micrometers.

- **How to apply:** For external diameter, wrap a Pi tape or use calipers around the pipe's outer surface to measure. For internal diameter, insert the caliper or micrometer inside the pipe and expand until it touches the sides. Measure at multiple points around the pipe to check for roundness and ensure even sizing.

✓ **Wall thickness measurement**

- **Tools:** Ultrasonic thickness gauge, micrometer.
- **How to apply:** For pipes with varying thickness, use an ultrasonic thickness gauge to measure at different spots. Position the gauge sensor on the pipe surface, and it will measure the thickness non-destructively. For small or thin-walled pipes, a micrometer can be used for more direct measurement.

✓ **Alignment and fit-up**

- **Tools:** Levels, spirit levels, squares, pipe clamps.
- **How to apply:** Levels and squares are used to check the vertical and horizontal alignment of the pipes during fit-up. Place a spirit level on the pipe to check for straightness or adjust the pipe for verticality. Use squares at joints to ensure the right angles, especially when welding perpendicular pipes.

✓ **Bevel angle measurement**

- **Tools:** Bevel gauge, protractor.
- **How to apply:** After cutting or preparing the pipe edges, use a bevel gauge to check the angle of the edge preparation (bevel). For beveled edges that will be

welded together, ensure the angle matches the specifications for optimal weld penetration.

- ✓ **Circumference measurement**

- **Tools:** Pi tape, flexible tape measure.
- **How to apply:** Wrap the Pi tape around the pipe to measure the circumference for joining similar or different pipe sections. Ensure the circumference matches at the weld joints, which helps prevent alignment issues or distortion during welding.

- ✓ **Gap and root opening measurement**

- **Tools:** Feeler gauge, gap gauge.
- **How to apply:** Position the feeler gauge between the edges of the pipe joints to ensure there is a proper root opening for weld penetration. Check multiple points around the circumference of the pipe to ensure the gap is uniform before starting the welding process.

- **Steps for applying measuring techniques in pipe and pressure vessel welding**

  - ✓ Identify the measurement requirements
  - ✓ Select appropriate measuring tools
  - ✓ Measure the pipe or vessel dimensions
  - ✓ Check joint alignment and fit-up
  - ✓ Verify wall thickness and roundness
  - ✓ Measure weld size and profile
  - ✓ Document and record measurements
  - ✓ Re-measure if necessary

- **Applying marking techniques.**
  - ✓ **Electrochemical marking**

Electrochemical marking in pipe and pressure vessel welding is a non-contact method that uses electrical current and electrolyte solutions to create permanent marks, such as serial numbers, batch codes, or manufacturer details, on metal surfaces.

- **Application:** It's ideal for marking stainless steel or alloy pipes used in pressure vessels because it produces highly durable and corrosion-resistant marks without compromising the material's integrity.

- ✓ **Inkjet marking**

Inkjet marking uses a stream of ink droplets to print alphanumeric codes, batch numbers, or barcodes onto pipe and vessel surfaces.

- **Application:** In welding applications, it is typically used for marking on non-porous surfaces like metals. While the mark may not be as permanent as other methods, it's useful for temporary marking during fabrication or inspection processes.

✓ **Laser marking**

Laser marking employs a concentrated beam of light to create precise, permanent marks by either vaporizing or etching the surface of the pipe or pressure vessel material.

- **Application:** This method is widely used in pipe and vessel welding because it offers high precision and durability, making it suitable for marking critical information such as part numbers, weld locations, or compliance marks on high-strength metals like carbon steel and stainless steel.

✓ **Scribing marking**

Scribing marking uses a hard-tipped tool to engrave text or symbols directly onto the surface of the pipe or vessel by physically cutting into the material.

- **Application:** This technique is often employed when deep, permanent markings are required, such as serial numbers or specifications on large pipes or vessels used in high-pressure environments. It's highly effective on metal surfaces, providing robust and long-lasting markings.

✓ **Dot peen marking**

Dot peen marking creates a series of small, controlled indentations on the surface of the pipe or pressure vessel to form characters or codes.

- **Application:** In welding and fabrication, this method is used to mark metals for identification purposes. It is particularly advantageous for heavy-duty environments, as the marks are resistant to wear, heat, and corrosion, making them ideal for marking on pressure vessels and pipes that may be subjected to extreme conditions.

- **Steps for applying marking techniques in pipe and pressure vessel welding**

  - ✓ Identify marking requirements
  - ✓ Select appropriate marking method
  - ✓ Prepare the surface for marking
  - ✓ Position the marking tool
  - ✓ Apply the marking to the surface
  - ✓ Verify accuracy of the marking
  - ✓ Document the markings if needed
  - ✓ Inspect and adjust markings if necessary

- **Positioning the work piece.**
  - ✓ **Positioning the workpiece in pipe and pressure vessels welding**

Positioning the workpiece in pipe and pressure vessel welding is a critical step to ensure accurate alignment, proper joint preparation, and optimal weld quality. It involves securing the pipe or vessel in the correct orientation before welding to prevent distortion, misalignment, or gaps during the welding process.

Steps for positioning work piece

- **Using clamps or jigs** to hold the pipe or vessel in place securely.
- **Aligning the weld joints** according to the specifications, ensuring that edges are properly matched.
- **Adjusting the angle and height** of the workpiece to provide access to the weld area and accommodate the welding technique being used (TIG, MIG, FCAW, etc.).
- **Double-checking the alignment** with measuring tools like levels, squares, or protractors to ensure precision before welding.

- **Apply cutting techniques.**
  - ✓ **Metal and pipe cutting methods**

In pipe and pressure vessel welding, metal and pipe cutting methods involve various techniques used to cut pipes and metal sheets to desired sizes and shapes, ensuring precise joint fit-up. Common cutting methods include:

- **Oxy-acetylene cutting**: Uses a flame to melt and cut metal, especially for thicker materials like steel.
- **Plasma cutting**: Uses a high-temperature plasma arc to cut through conductive metals with high precision.
- **Mechanical cutting**: Includes tools like band saws, chop saws, and angle grinders for cutting pipes and metal plates with accuracy.
- **Laser cutting**: Ideal for precision cutting of thinner materials with minimal distortion.

✓ **Guide cutting attachment**

Guide cutting attachments are devices used to ensure straight, precise, and uniform cuts on pipes or metal. These attachments are often fitted onto cutting tools such as oxy-acetylene torches or plasma cutters. They help guide the tool along a set path, maintaining the correct angle and distance for cutting. These attachments are useful in avoiding human error and improving the quality and consistency of cuts, especially in applications requiring high precision, such as pressure vessel fabrication.

✓ **Template development**

Template development refers to creating a pattern or model used as a guide for cutting or shaping metal parts, especially for complex shapes or angles in pipe welding. Templates can be made from materials like cardboard, metal sheets, or plastic, and are used to trace or mark the workpiece before cutting or welding. In pipe welding, templates are often used to mark cut lines on pipes for fitting and welding, ensuring proper alignment and joint preparation. Accurate template development is essential to minimize material waste and ensure a proper fit during welding.

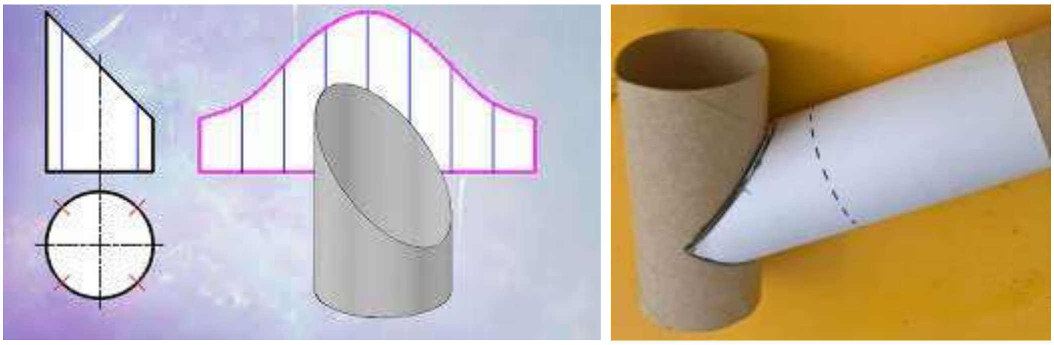


Figure 76: pipe template

- **Procedures of template development**

- Determine the welding joint type: Identify the required weld joint (e.g., butt, T-joint, miter, saddle, or branch connection) to influence the shape and complexity of the template.
- Measure the pipe dimensions: Accurately measure the pipe's diameter, wall thickness, and length to ensure the template's proper fit.
- Calculate angles and cut shapes: Use geometric calculations or layout tools to determine the required cut profiles, especially for complex shapes like saddle joints.
- Draw the template pattern:
- Use paper or cardboard to create a manual template, marking key points.
- Alternatively, design a digital template using CAD for precise cutting via CNC machines.
- Transfer the template to the pipe: Wrap the template around the pipe and mark it for cutting using a chalk or paint marker. Metal stencils can be used for repeated cuts.
- Cut the pipe: Follow the template markings using appropriate cutting tools (e.g., torch, plasma cutter, or band saw) for smooth, accurate cuts.

- Fit-up and inspection: Dry-fit the cut pieces, checking for proper alignment and adjusting as needed.
- Welding preparation: Clean the cut edges, align the pieces, and tack weld them before completing the final weld.

- **Procedures for applying cutting techniques**
  - ✓ **Metal and pipe cutting methods**

- **Preparation**: Secure the workpiece using clamps or vices to prevent movement during cutting.
- **Marking**: Measure and mark the cutting lines on the pipe or metal using appropriate marking tools.
- **Select cutting method**:
  - For **oxy-acetylene cutting**, adjust the flame and preheat the metal before cutting along the marked line.
  - For **plasma cutting**, set the machine to the appropriate amperage and speed, and guide the torch along the marked line.
  - For **mechanical cutting**, use a band saw or chop saw with the appropriate blade for the material thickness.
- **Cutting**: Follow the marked lines, maintaining a steady speed and angle to ensure precision.
- **Finishing**: After cutting, deburr the edges using a grinder or file to smooth the cut.

✓ **Guide cutting attachment**

- **Select the guide attachment**: Choose the appropriate cutting guide attachment based on the tool and material.
- **Attach to the cutting tool**: Secure the guide to the torch, plasma cutter, or mechanical cutting tool, ensuring it is properly aligned.
- **Set the cutting path**: Place the guide against the surface of the workpiece, aligning it with the cutting line.
- **Perform the cut**: Start the cutting process, allowing the guide to direct the tool along the straight or curved path.
- **Inspect the cut**: After cutting, ensure that the line is straight or conforms to the desired shape.

✓ **Template development**

A manufacturing template serves as a physical or digital reference that outlines specific dimensions, shapes, or layouts for parts, assemblies, or processes.

Types of templates

- **Cutting templates**

Used for guiding cutting tools in processes such as machining, laser cutting, and routing.

Often made from materials like metal, plastic, or wood, these templates help achieve consistent cuts.

- **Assembly templates**

Assist in aligning and positioning parts during assembly.

They can include jigs and fixtures that hold components in place, ensuring accurate assembly.

- **Drilling templates**

Provide a guide for drilling holes in specific locations on a workpiece.

Commonly used in woodworking and metal fabrication to ensure holes are drilled at the correct angles and distances.

- **Welding templates**

Used to position and align components for welding.

Ensure that joints are consistently placed and that the workpieces are held securely during the welding process.

- **Inspection templates**

Serve as standards against which finished products are measured to ensure they meet quality specifications.

Can include gauges or physical templates that represent acceptable tolerances.

Benefits of using templates

- **Reduced errors:** By providing a clear guide, templates help minimize human errors that can occur during measurement and setup.
- **Time savings:** Templates streamline setup times for machines and workstations, allowing for quicker transitions between tasks.
- **Improved quality Control:** Templates facilitate more effective inspections, leading to higher quality products and less waste.

How to crate template

- **Create the template**: Using the required dimensions, create a template out of cardboard, plastic, or metal for the desired shape or angle.
- **Place the template on the workpiece**: Position the template on the metal or pipe, ensuring it is correctly aligned with the cutting area.
- **Trace the template**: Using a marker or scribe, trace the outline of the template onto the workpiece.
- **Cut along the marked line**: Follow the template's outline using your selected cutting method, ensuring the cuts are precise.
- **Check fit**: After cutting, check the fit of the cut piece against the intended structure, adjusting as necessary.

Points to Remember

- Choosing the right method to cut a workpiece depends on the material, thickness, required precision, and available equipment. Whether using mechanical tools like saws, thermal methods like plasma or laser cutting, or manual techniques, proper preparation, safety measures, and cutting techniques will ensure an efficient and precise result.
- Proper positioning is essential for achieving strong, defect-free welds, particularly in application.
- Accurate measurements can be ensured throughout the fabrication and welding process, preventing defects and ensuring safety in pipe and pressure vessel projects.

Application of learning 2.1.

In your school manufacturing workshop, there are a selected metal plates and pipes to be cut the pieces required for assembling $3m^3$ cylinder petroleum tank with input and output pipes but there is no special worker for cut pipes and palate metals. You are asked to cut the workpieces required for the task.

Indicative content 2.2: Preparing Edge of the Workpiece

Duration: 10 hrs

Practical Activity 2.2.1: Preparing edge of the workpiece

Task:

You are requested to go in manufacturing workshop and prepare the edge of workpieces as required for pipes and pressure vessels welding process based on preparation criteria.

1: Apply safety precautions

2: prepare the edge of workpieces as required for the work.

3: Present your work to the trainer and whole class.

4: Read key reading 2.2.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 2.2.

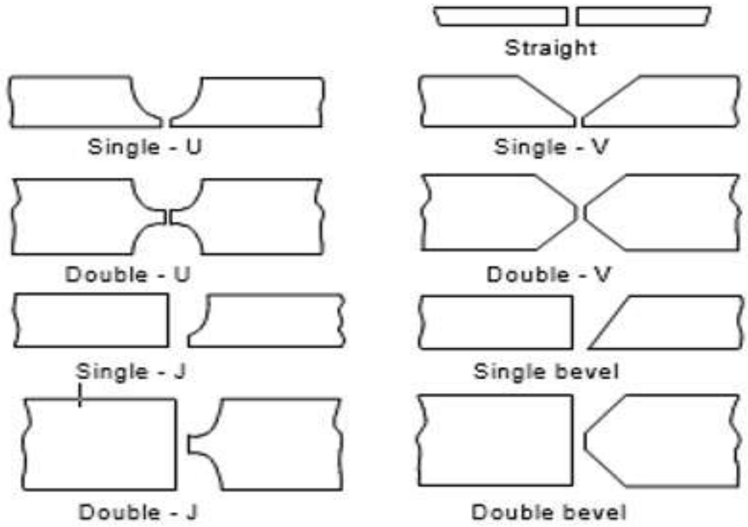
Key readings 2.2.1: Preparing edge of the workpiece

- **Edge preparation in welding**

Edge preparation in welding refers to the process of preparing the edges of metal parts or components to be welded. It involves shaping or machining the edges of the workpieces in specific ways to ensure proper fusion between the parts, adequate penetration, and strong, defect-free welds. Proper edge preparation is especially important for thicker materials, where a simple butt joint may not provide enough penetration for a strong bond.

✓ **Types of edge shapes**

Before TIG, MIG/MAG, FCAW welding process, as other type of welding, the edges of joining surfaces of metals are prepared first.



✓ **Procedures of edge preparation**

Material inspection

- Check the material's type, thickness, and dimensions.
- Inspect for surface defects, rust, or dirt that could affect the welding process.
- Confirm the material's weldability based on its composition.

Marking the edges

- Use a measuring tool (e.g., ruler, tape measure) to mark the edges that will be beveled or shaped.
- Mark the desired bevel angles, chamfers, or grooves on the metal using chalk or markers.
- Follow the welding procedure specification (WPS) for the appropriate edge shape.

Cutting the edges

- Cut the metal along the marked lines to create the basic edges of the joint.
- Ensure the cut is smooth and free from irregularities.
- For thicker materials, allow extra metal to be removed later during beveling.

Edge beveling

- Set the beveling machine or grinder to the specified angle (e.g., 30°, 45°).
- Bevel the edges to the desired depth, ensuring uniformity along the length of the edge.
- For U-grooves or J-grooves, use precision tools to create the curved profile.

Cleaning the edges

- Apply degreaser or solvent to remove oils and other contaminants.
- Use a wire brush or grinder to clean any surface rust, scale, or dirt from the edges.
- Ensure the edges are completely clean and dry before welding.

Checking the prepared edge dimensions

- Measure the bevel angle and groove dimensions to ensure they meet the welding procedure specification (WPS).
- Ensure that the thickness of the root face (land) is consistent and within the specified tolerance.
- Check that the root gap (the space between the two pieces) is uniform and matches the joint design.

Deburring the edges

- Smooth out the edges using a file or grinder to remove any imperfections.
- Ensure the edges are free from sharp burrs or unevenness, as this can affect the weld quality.

Fit-up and alignment

- Bring the prepared edges together, ensuring the proper root gap, alignment, and bevel angle.
- Use clamps or tack welds to temporarily hold the pieces in place for final welding.
- Recheck the alignment and fit-up against the specified tolerances.

Final inspection before welding

- Inspect the edges for cleanliness, uniformity of bevels, and proper alignment.
- Ensure that there is no contamination (e.g., grease, oil, dirt) on the prepared surfaces.
- Confirm that the prepared edges meet all specifications in the welding procedure.

✓ **Advantages of edge preparation**

- Edge preparation makes it easier to get a stronger bond via Welding and adding filler metal.
- Edge preparation provides access for the Welding operation.
- It provides an area where some filler metal can be added.
- This makes the weld/joint very strong and can be subjected to greater amount of load.

✓ **Disadvantages of edge preparation**

- Sharped workpieces can cause accident like injuries, even death.
- During edge preparation it requires experiences for doing it.
- Poor edge preparation may cause welding defects and/or poor weldment on edges

✓ **Applications of edge preparation**

- Edge preparation is used in welding heavy equipment manufacturing industry
- It may be used to some extent in welding industrial piping.
- The edge preparation is used in welding of thick plates in industries.
- It is also used in maintenance and bridges fabrication.

Points to Remember

- The technique selected will depend on the material type, project requirements, and desired outcome.
- Proper edge preparation ensures strong, reliable welds that meet mechanical and structural requirements.

Application of learning 2.2.

In your school manufacturing workshop, there are the cut workpieces for assembling cylindrical aluminum tank of 10 m^3, but the edges of pieces are not prepared. You are asked to prepare the workpiece edges.

Indicative content 2.3: Forming the Workpiece

Duration: 10 hrs

Practical Activity 2.3.1: Applying bending techniques

Task:

You are requested to go in manufacturing workshop and bend the workpieces as required for pipes and pressure vessels welding process based on bending techniques.

1: Apply safety precautions

2: Bend the workpieces as required for the work.

3: Present your work to the trainer and whole class.

4: Read key reading 2.3.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 2.3.

Key readings 2.3.1: Applying bending techniques.

- **Cold bending**

  Cold bending refers to the process of bending a material at or near room temperature, without applying heat. In this method, the material is gradually deformed using mechanical force, typically through the use of specialized bending tools or machines.

Advantages of cold bending

- Cold bending preserves the structural integrity and properties of the material being bent.
- Cold bending eliminates the need for expensive heating equipment and energy consumption associated with hot bending.
- Cold bending allows for precise and accurate bending of materials.
- Cold bending is generally a faster process compared to hot bending. Since there is no need to wait for materials to reach specific temperatures or cool down.
- Cold bending is versatile and can be applied to a wide range of materials, including steel, aluminium, stainless steel, and more.

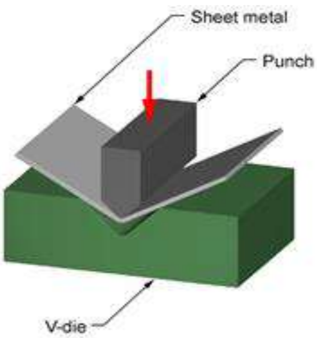
Disadvantages of cold bending

- Limited bending capacity: Cold bending has certain limitations in terms of the maximum bend radius and the degree of curvature that can be achieved.
- Spring back: Cold bending can result in spring back, which is the tendency of the material to return partially to its original shape after being bent.
- Increased force requirements: Cold bending typically requires higher force compared to hot bending. This can be a limitation when bending thicker or harder materials, as it may require specialized equipment
- Surface imperfections: Cold bending can sometimes cause surface imperfections, such as scratches or marks, due to the contact between the material and the bending tools or dies.

Types of cold bending

1. Air bending

Air bending is a common cold bending technique where the material is bent using a punch and die without full contact along the entire length of the material. The material is bent by applying force at the bend point, allowing for flexibility in achieving different bend angles.



Air Bending

- **Advantages of air bending:**

a. Air bending offers versatility in achieving a wide range of bend angles and shapes.

b. Reduced Tooling Costs: Air bending requires fewer specialized tooling or dies compared to other bending methods.

c. Air bending can be set up relatively quickly compared to other bending methods.

- **Disadvantages of air bending**

a. Air bending can result in a higher degree of springback compared to other bending methods.

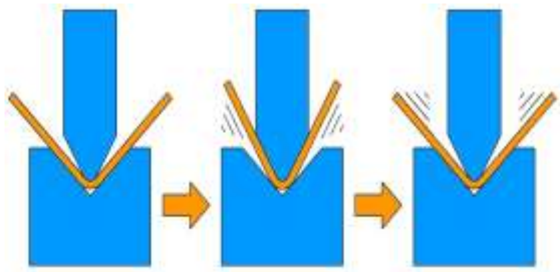
b. Less Control over Bend Angle: Air bending may have slightly less control over the final bend angle compared to other bending methods.

c. Limited Bending Capacity: Air bending has limitations in terms of the maximum bend radius that can be achieved.

d. Reduced Accuracy for Thin Materials as the lack of full contact along the entire length of the material can result in slight variations in the bend angle.

2. Bottoming

Also known as bottom bending or die bending, the punch and die are brought together so the material contacts the punch tip and the V-opening sidewalls. bottoming only uses a V-shaped die.



- **Advantages of bottoming**

a. Greater accuracy
b. Precise and Consistent Bending
c. Suitable for Thick and Hard Materials
d. less springback.

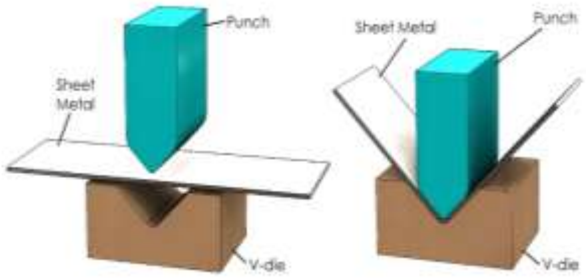
- **Disadvantages**

a. Surface Marking or Scratching
b. Longer Setup Time

c. Bottoming requires specialized tooling, including a punch and a bottom die, which can be more complex and expensive compared to other bending methods.

3. Coining

The term 'coining' comes from coin-making, is squeezing operation in which the metal flows into the cavity between the punch and die, Machines using extremely high tonnage compressed a metal disc with enough force to make it conform to the image inscribed on the die set.



- **Advantages of coining**

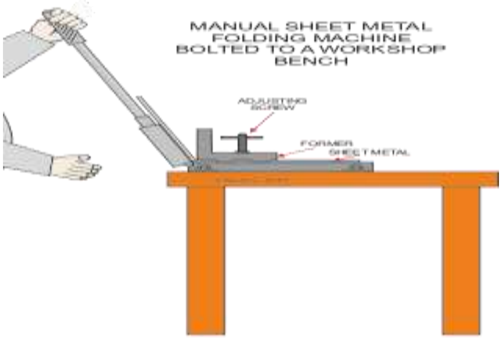
a. Highly accurate and precise bend
b. Minimal spring back and distortion
c. Coining can improve the surface finish of the bent material
d. Increased Material Strength

- **Disadvantages**

a. Equipment and Tooling Costs is High
b. Surface Marking or Damage
c. Suitable for softer materials that can withstand the high pressure applied during the bending process.
d. Complex Setup and Maintenance

4. Folding

Folding is a metalworking operation that involves bending a sheet metal or other flat material along a straight line to create a sharp fold or crease. The material is positioned between the punch and die of the folding machine, and the machine is activated to apply force along the marked line. The force causes the material to bend and form a sharp fold or crease along the designated fold line.



- **Advantages of folding**

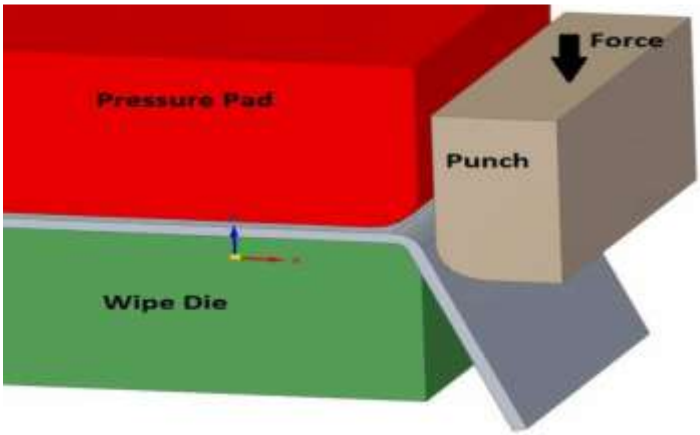
- Precise and Consistent Bends
- Cost-Effective
- Efficient Production

- **Disadvantages of folding**

- Limited Bend Angle
- Material Thickness Limitations
- Surface Imperfections

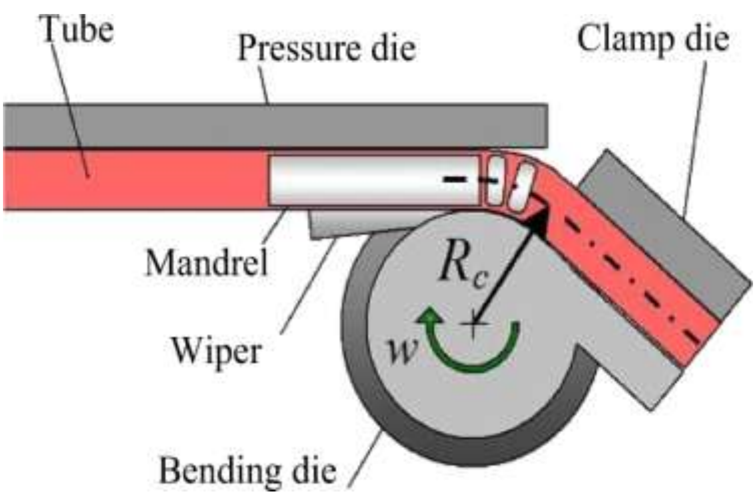
5. Wiping

In wiping, the longest end of the sheet is clamped, then the tool moves up and down, bending the sheet around the bend profile. Though faster than folding, wiping has a higher risk of producing scratches or otherwise damaging the sheet, because the tool is moving over the sheet surface. The risk increases if sharp angles are being produced.



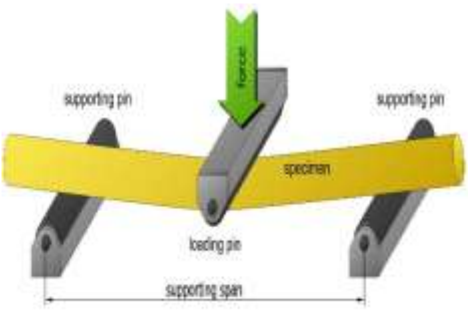
6. **Rotary bending**

Rotary Bending is accomplished by bending the Pipe or Tube on a fixed die set machined to fit the exact outside diameter. A mandrel is inserted inside the Pipe or Tube to prevent collapse during the bending process. Square and rectangular materials can also be bent. Multiple bend configurations can be produced greatly reducing the amount of welding and polishing required. Rotary bending is similar to wiping but the top die is made of a freely rotating cylinder with the final formed shape cut into it and a matching bottom die. On contact with the sheet, the roll contacts on two points and it rotates as the forming process bends the sheet.



7. **Three-point bending**

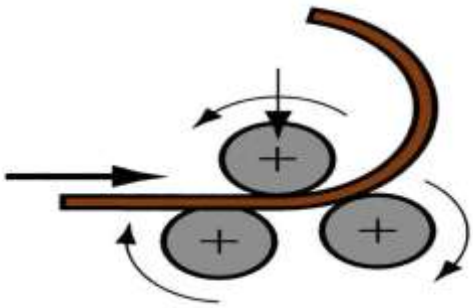
Bending a piece of metal by placing the specimen on two supports and then appl ying a load on it between the supported ends.

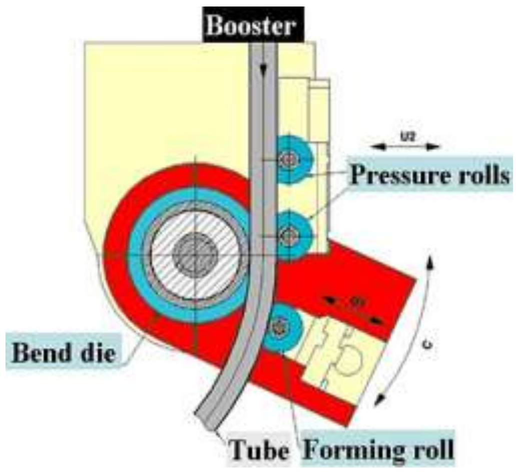


8. **Roll Bending**

The steel tube is made to pass through a set of three rollers that, after one or more passages (depending on the difficulty of bending), will form an arc with the required radius of curvature. It is a process whereby obtain wider bend radius. It is a simpler process than bending.

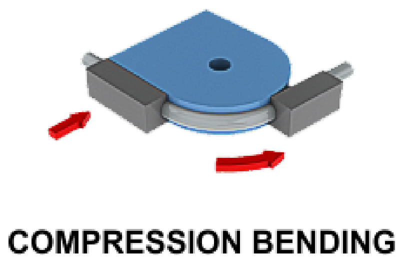
The particular feature of this type of mechanical process is that a single machine can produce different bend radii on the same tube, permitting the creation of complex geometrical shapes. The disadvantage of roll bending is the fact that in order to achieve a valid gripe and begin the roll-bending process, the machine requires a portion of additional material at the beginning and end of the tube.

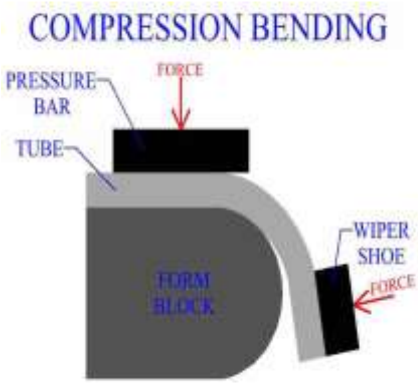




9. **Compression Bending**

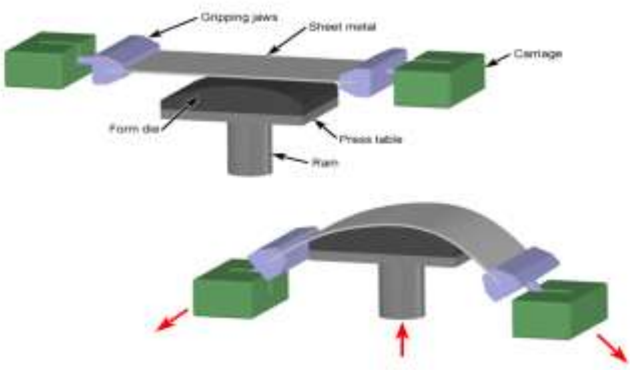
Compression bending, also known as squeeze bending, involves applying compressive force to the material to achieve the desired bend. It involves bending a piece of tubing using a roller/compression die, which bends the tubing around a bend die which is stationary. The tubing is clamped to the system, and the roller then works to compress the tubing against the central bend die.





10. **Stretch**

It involves bending a sheet metal or other flat material by stretching it over a form or die as the stretching force is applied, the sheet metal gradually bends and conforms to the shape of the form or die. The stretching force is carefully controlled to achieve the desired bend angle and radius without causing excessive deformation or material failure.



- **Steps for cold bending**

Steps for cold bending

Step 1: Material selection:

- Choose the appropriate material based on its properties, thickness, and intended use. Common materials for cold bending include mild steel, stainless steel, and aluminium.

Step 2: Design and measurement:

- **Plan the bend**: Determine the desired angle and radius of the bend. Accurate planning is crucial for achieving the desired shape.
- **Measure**: Use measuring tools (like a tape measure or caliper) to mark the metal sheet or bar where the bend will occur. Clearly mark the bend line and any reference points for precision.

Step 3: Preparation of the material:

- **Cut the material**: If necessary, cut the metal to the desired length before bending. Ensure that cuts are straight and clean to avoid complications during bending.
- **Deburr the edges**: Remove any sharp edges or burrs from the cut metal to prevent injury and ensure a smooth bending process.

Step 4: Select the bending method:

- Choose an appropriate cold bending method based on the material and the desired outcome. Common methods include:

- **Manual bending**: Using hand tools like pliers or a bending lever.
- **Mechanical bending**: Using a bending machine or hydraulic press.
- **Roll bending**: Utilizing a roll bender for creating curves in sheets or plates.

Step 5: Set up the bending equipment:

- If using a bending machine, adjust the settings according to the material's thickness and type.
- For manual methods, secure the metal piece in a vise or clamp to hold it steady during the bending process.

Step 6: Perform the bending:

- **Gradual bending**: Apply force gradually, avoiding sudden pressure that could lead to cracking or deformation. If using a machine, follow the operational guidelines for best results.
- **Control the bend radius**: For tighter bends, use a proper die or form to maintain consistency and prevent kinking or wrinkling of the material.

Step 7: Check the bend:

- After the initial bend, check the angle and radius against the measurements taken earlier. Adjust as needed to ensure accuracy.
- If necessary, perform additional bends to achieve the final desired shape.

Step 8: Final inspection:

- Inspect the bent metal for any defects, such as cracks, warping, or surface damage. Ensure that the dimensions match the specifications.
- Perform any necessary finishing processes, such as grinding or sanding, to smooth out rough edges or surface imperfections.

Step 9: Post-bending treatments (optional):

- Depending on the material and application, consider applying a protective coating (such as paint or galvanization) to prevent corrosion.
- Conduct any additional machining or assembly as needed for the final application.

- **Hot bending**

  Hot bending Also known as heat-assisted bending, involves bending a material while it is heated to an elevated temperature. The material is heated above its recrystallization temperature, which makes it more malleable and easier to deform. Hot bending is typically performed using heat sources such as torches, furnaces, or induction heaters.

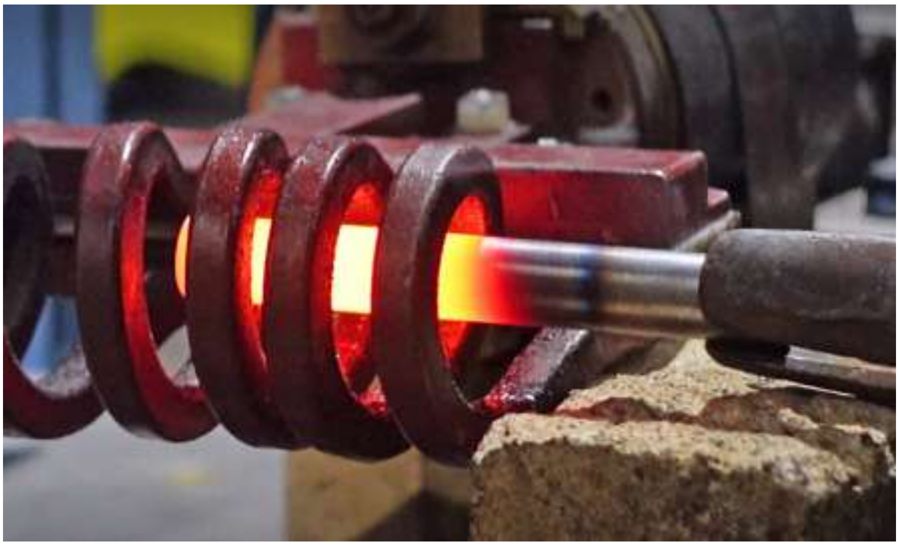
  the primary advantage of hot bending is that the material yield strength is lowered from the room temperature value, requiring smaller forces to be exerted by the bending machine.

  Heat is applied directly to the member by flame, by heating in a furnace, or by induction coil, followed by the application of a bending force. The member can be bent around preset forms, but more often the bending force is applied using one of the previously discussed bending methods.

Induction bending

Is an advanced metal bending process, offering optimum precision, efficiency and consistency? It is suitable for a very wide range of applications and completely overcomes the potential limitations of cold bending techniques, such as distortion and wall thinning.

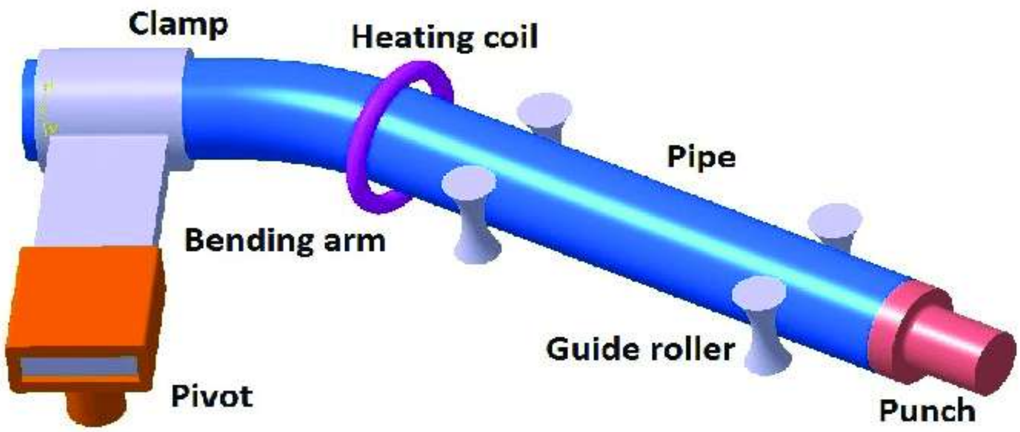
Straight pipe, tube or other section types are placed on a machine bed with a swing arm set to the required radius. The material is then hydraulically pushed through an induction coil at a carefully controlled and monitored rate. Heat of approximately 1000°C is solely focused on the area which requires bending, while cool air and water is sprayed on the area adjacent to the heated zone. The combination of speed, heat and cooling allows sections to be bent to tighter radii without cross sectional deformation.



- **Materials suitable for induction bending include:**

➢ Carbon steels

- Case hardened and tempered steels
- High chrome materials
- High yield steels
- Low temperature materials
- Specialist steels
- Stainless steels



- **Advantages of using induction bending**

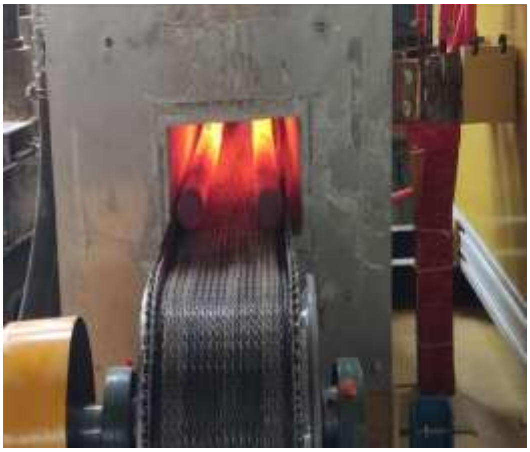
- Induction bending offers the ability to bend various types of materials and wide range of material thicknesses and diameters
- Reduced Distortion and Material Stress
- Induction bending can lead to cost savings compared to other bending methods.
- Induction bending provides precise and consistent bends with tight tolerances.
- Induction bending enables the creation of complex and intricate bend shapes.

- **Disadvantages of induction bending**

- Induction bending involves the heating and cooling of the material, which can result in longer cycle times compared to other bending methods.
- Skill and Expertise Requirements
- The length of the material that can be effectively induction bent may be limited.
- Limited Bend Radius
- Induction bending requires specialized equipment and tooling, which can be costly to acquire and maintain.

Furnace bending

Furnace bending is a specialized technique in which metal or other materials are heated in a furnace to make them more malleable before bending. This process is commonly used for materials that are too thick, hard, or brittle to be bent effectively at room temperature.



- **Steps in furnace bending:**

Step 1: Material preparation:

- The material, typically metal is prepared by cutting it to the desired length and size.
- The edges and surfaces may be cleaned to remove any impurities, ensuring a smooth bend and preventing defects during the process.

Step 2: Heating in the furnace:

- The material is placed inside a furnace, which is heated to a specific temperature depending on the material's properties. For metals, the temperature is usually above the material's recrystallization point (but below its melting point).
- **Time in the furnace** is carefully monitored to ensure the material reaches the proper pliable state. Overheating can weaken the material, while underheating can result in poor bends.

Step 3: Bending:

- Once the material is sufficiently heated, it is removed from the furnace and immediately bent into the desired shape.

- The bending process can be done manually or with the help of hydraulic presses, jigs, or rollers.
- The material is bent slowly to ensure a smooth, even curvature without causing cracks or stress points.

Step 4: Cooling:

- After bending, the material is allowed to cool either naturally (slow cooling) or rapidly through quenching (immersing the material in water or oil).
- The cooling method used depends on the type of material and the desired mechanical properties. For instance, rapid cooling can harden certain metals, while slow cooling may be used to retain flexibility.

Step 5: Finishing:

- After cooling, the bent material may undergo additional finishing processes, such as grinding or polishing, to smoothen the edges and surfaces.
- The bent component is inspected for accuracy, defects, and quality before being used in further applications.

- **Advantages of furnace bending:**

- **Improved Bend Quality**: Heating the material allows for smoother, more controlled bends with fewer imperfections, such as cracking or wrinkling.
- **Bending Thick or Hard Materials**: Furnace bending is ideal for materials that are difficult to bend using cold methods, such as thick steel, copper, or glass.
- **Retained Structural Integrity**: By heating and bending the material, furnace bending reduces the likelihood of creating stress points or weakening the material during the bending process.

- **Disadvantages of furnace bending:**

- **Energy Consumption**: Furnace bending requires significant energy to heat the material to the required temperature, making it more expensive than cold bending techniques.
- **Time-Consuming**: The process can be slower compared to cold bending, as it involves heating, bending, and cooling stages, each of which requires careful control and monitoring.
- **Specialized Equipment**: The process requires a furnace and specialized bending tools, which may not be available in all fabrication shops, leading to higher costs.

Torch bending

Torch bending is a metalworking process that involves heating specific sections of a metal workpiece using an oxy-fuel torch or other high-temperature torch, making it malleable enough to bend by applying force. This technique is particularly useful for bending metal pipes, bars, or sheets that are too thick or strong to be bent cold, or for making minor adjustments in shape after a piece has been initially formed.

- **Steps in torch bending:**

Step 1: Preparation

- The metal to be bent is measured and marked to indicate the specific area where the bend is needed.
- The work area is cleared of any flammable materials, and proper safety equipment, such as gloves, goggles, and flame-resistant clothing, is worn.
- The type of metal (e.g., steel, aluminum, copper) is considered to determine the appropriate heating temperature.

Step 2: Heating the metal

- An oxy-acetylene or propane torch is typically used to direct high heat onto the metal, focusing on the bend area. The flame is controlled to avoid overheating or burning the metal.
- The metal is heated to a temperature where it becomes soft and pliable but not melted. The color change in the metal (often turning red or orange) is an indicator that it's ready to be bent.
- **Heat distribution** is key—heating too large of an area can lead to a weak or distorted bend, while heating too small of an area can cause cracks or stress points.

Step 3: Bending

- Once the metal reaches the desired temperature, it is bent either manually or with the help of tools, such as wrenches, pliers, or clamps. Larger or thicker materials may require hydraulic jacks or presses to apply sufficient force.
- The bend should be made slowly and carefully to ensure that it is smooth and even. If necessary, the torch can be applied intermittently during the bending process to maintain the pliability of the material.

Step 4: Cooling

- After the desired bend is achieved, the metal is allowed to cool, either naturally (air cooling) or through rapid cooling using water or oil quenching, depending on the type of metal and the required mechanical properties.
- Air cooling tends to preserve the metal's toughness, while rapid cooling can harden the material but may make it brittle in some cases.

Step 5: Finishing

- Once cooled, the bent area is inspected for defects such as cracks, warping, or inconsistent bends.
- If necessary, the metal can be ground, filed, or polished to remove any rough edges or imperfections caused by the heating process.

- **Advantages of torch bending**

- Flexibility: Torch bending allows for precise, small-scale adjustments in metal shapes, making it ideal for custom or repair work.
- Cost-Effective: It's a relatively simple and inexpensive method compared to using hydraulic presses or CNC bending machines, especially for small or one-off jobs.
- Portable: Torches are easy to transport, making this technique suitable for on-site work or in locations where large equipment cannot be used.
- Adjustments on Existing Parts: Torch bending can be applied to pre-formed parts or materials that need minor tweaks or adjustments, unlike many other bending techniques.

- **Disadvantages of torch bending**

- Limited to Minor Bends: Torch bending is generally not suitable for large, complex, or high-volume bending jobs. It works best for minor adjustments or small bends.
- Potential for Warping: Uneven heating or excessive heat can cause warping or other defects in the metal, making it crucial to carefully control the temperature and heat distribution.

- ➢ Requires Skill: Proper torch bending requires experience and skill to ensure that the metal is heated evenly and bent without damaging its structural integrity.
- ➢ Heat-Affected Zones: The localized heating of the metal can create heat-affected zones (HAZ), where the material's properties (such as hardness or strength) are altered. This can affect the metal's overall performance in some applications.

- **Comparison of hot bending and cold bending**

- **Material Size**: Hot bending is better for thicker, harder materials, while cold bending is suited for smaller, thinner, or more ductile materials.
- **Energy Consumption**: Hot bending requires additional energy for heating, while cold bending is more energy-efficient.
- **Precision**: Cold bending offers more precise control for smaller bends, while hot bending is necessary for more complex or large-scale projects.

Practical Activity 2.3.2: Applying rolling techniques

Task:

You are requested to go in manufacturing workshop and roll the workpieces as required for pipes and pressure vessels welding process based on bending techniques.

1: Apply safety precautions

2: Roll the workpieces as required for the work.

3: Present your work to the trainer and whole class.

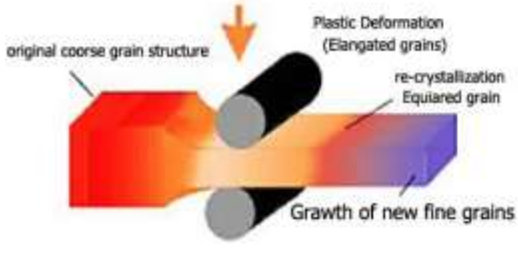
4: Read key reading 2.3.2 and ask clarification where necessary.

5: Perform the task provided in application of learning 2.3.

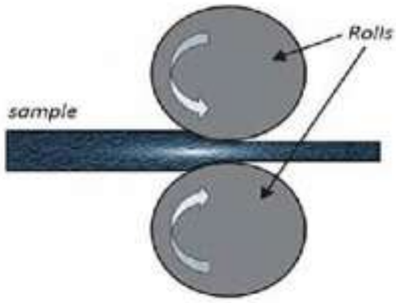
Key readings 2.3.2: Applying rolling techniques.

- **Rolling**

Rolling technology uses rotating rolls to cause plastic deformation of SMAs, by applying squeezing pressure to obtain the desired shape and properties. Rolling techniques can be divided into cold and hot rolling, based on the temperature during the rolling operation.



Hot Rolling Process



Cold Rolling Process

Rolling is a process used to shape metal into a thin long layer by passing it through a gap of two rollers rotating in different directions (clockwise and anti-clockwise)

✓ **Hot rolling**

Hot rolling is a metalworking process that involves rolling steel and other metals at high temperatures, typically above the material's recrystallization temperature. This makes the metal more malleable and easier to shape.

Process steps

Step 1: Heating the metal:
- ➢ The metal is heated in a furnace to a temperature above its recrystallization point (typically 1,700°F or 926°C for steel).

Step 2: Feeding the material:
- ➢ Once heated, the material is transferred to the rolling mill for processing.

Step 3: Rolling:
- ➢ The heated metal is passed through rollers, which reduce its thickness and shape it into the desired form. The rollers apply pressure from both sides, flattening and elongating the metal.
- ➢ The metal can be rolled in different configurations, including flat, round, or shaped sections.

Step 4: Cooling:
- ➢ After rolling, the metal is allowed to cool in the air. This cooling process is often uncontrolled, leading to different microstructures within the material.

Step 5: Finishing:
- ➢ After cooling, the rolled metal may undergo finishing processes such as cutting, surface treatment, or coating.

- **Advantages**

- ➢ Improved workability due to reduced strength at high temperatures.

- Can produce large shapes and forms with minimal force.
- More uniform thickness and better mechanical properties compared to cold-rolled products.

✓ **Cold rolling**

Cold rolling is a process where metal is rolled at or near room temperature, typically below the recrystallization temperature. This results in a stronger and harder material due to strain hardening.

Process steps

Step 1: Preparation:

- The metal is first cleaned to remove any scale or oxidation from the surface before rolling.

Step 2: Feeding the material:

- The prepared metal is fed into the cold rolling mill, which typically operates at room temperature.

Step 3: Rolling:

- The metal passes through a series of rollers that apply significant pressure, reducing its thickness and altering its shape. Cold rolling can involve multiple passes through the rollers to achieve the desired specifications.

Step 4: Annealing (Optional):

- Depending on the application, the rolled metal may undergo an annealing process to relieve internal stresses and improve ductility. This is not always necessary but can be beneficial for certain materials.

Step 5: Finishing:

- After rolling, the metal may be trimmed, coated, or otherwise processed for the final product.

- **Advantages**

- Higher yield strength and better surface finish compared to hot-rolled products.
- Better dimensional tolerances and surface quality.
- Increased hardness due to strain hardening.

Key differences between hot rolling and cold rolling

Aspect	**Hot rolling**	**Cold rolling**

Temperature	Above recrystallization temperature	At or near room temperature
Material properties	More malleable, less strength	Stronger, harder due to strain hardening
Surface finish	Rougher surface, scale may be present	Smoother surface finish
Dimensional tolerance	Lower tolerance	Higher tolerance
Applications	Structural shapes, heavy sections	Precision components, sheets, and strips

Points to Remember

- cold rolling is preferred for achieving high-strength materials with precise dimensions and surface finishes.
- After bending, allow the material to cool slowly and evenly to prevent warping or residual stresses.
- Overheating can lead to material degradation or loss of mechanical properties.

Application of learning 2.3.

In your school manufacturing workshop, there are a prepared workpiece to be formed for assembling mild steel pipes and cylindrical gas tank of 5 m^3. You are asked to form the workpieces as required.

Learning outcome 2 end assessment

Theoretical assessment

Q1. Read the following statement and answer by **TRUE** if it is correct or **FALSE** if it is incorrect.

a. Plasma cutting is an effective method for cutting non-conductive materials.
b. Edge preparation is not necessary when welding thin materials.
c. Beveling is only required for MIG welding, not for TIG or FCAW welding.

Q2**.** Read the following statement and re-write the letter corresponding to the correct answer

i. **Which tool is commonly used for measuring the length of a pipe?**

a) Micrometer

b) Pi tape

c) Tape measure

d) Ultrasonic thickness gauge

ii. **Which of the following tools is used to measure the internal diameter of a pipe?**

a) Vernier calipers

b) Pi tape

c) Ultrasonic thickness gauge

d) Laser measuring device

iii. **Which of the following is a primary reason for proper edge preparation in welding?**

a) To reduce the amount of filler metal needed

b) To improve the aesthetic appearance of the weld

c) To ensure proper fusion and adequate penetration

d) To simplify the alignment process

iv. **Which step involves removing oils and contaminants from the edges of the workpiece?**

a) Edge beveling

b) Deburring the edges

c) Cleaning the edges

d) Fit-up and alignment

v. **Which cold bending technique involves minimal contact between the material and the tools?**

A) Air bending

B) Bottoming

C) Coining

D) Wiping

Q3. Read the following sentence and complete the blank space with **(coil, springback, Cold, Rotary)**

a) Cold bending typically results in _________, which is the tendency of the material to return to its original shape after being bent.

b) _________ rolling is done at room temperature and results in a stronger, harder material.

c) In _________ bending, a mandrel is inserted inside the pipe to prevent collapse during the process.

Q4. Table below contain job hazard and types of hazards, match column of job hazards to hazards types column and provide the answer in provided space.

Answer	**Bending technique**	**Description**
A=…..	A. Metal is heated in a furnace before being bent	**1.** Wiping
B=……	B. A mandrel is used inside the pipe to prevent collapse	2. Torch bending
C=…..	C. Clamping one end and bending around the profile	3. Rotary bending
D=…..	D. Applying high heat with a torch to soften the metal	4. Furnace bending
		2. Coining

Practical assessment

AB is a metal product assembling company located in MUSANZE district. They have received a tender of fabricating fuel pressure vessel of 100m^3 made in stainless steel with inlet and out let pipes, but there is no specialized worker for pipes and pressure vessels welding. Due to the reason described, you are asked to:

1. Cut workpieces required for fabricating fuel pressure vessel
2. Prepare the edge of workpiece as required for fabricating fuel pressure vessel
3. Form the workpieces as required for fabricating fuel pressure vessel

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Learning Outcome 3: Assemble Pipes and Pressure Vessels.

Indicative contents
3.1 Joining pipes and pressure vessels **3.2 Finishing the product** **3.3 Testing the product**

Key Competencies for Learning Outcome 3: Assemble Pipes and Pressure Vessels.

Knowledge	Skills	Attitudes
• Identification of alignment tools • Description of alignment Methods • Identification of pipes and pressure vessels welding methods • Description of weld types • Description of weld defects	• Aligning the workpieces • Applying pipes and pressure vessels welding methods • Applying types of welds • Applying finishing methods • Applying surface protection techniques • Applying testing techniques • Correcting the weld defects	• Being accurately in workpieces aligning • Being attentive while applying the pipes and pressure vessels welding methods • Having precision while applying types of welds • Being creator while applying surface protection techniques • Being carefully while applying testing techniques • Being attentive in correcting weld defects

Duration: 50 hrs

Learning outcome 3 objectives:

By the end of the learning outcome, the trainees will be able to:

1. Identify correctly the alignment tools used in pipes and pressure vessels welding
2. Describe properly the alignment methods as applied in pipes and pressure vessels
3. Align properly workpieces as required in pipes and pressure vessels welding
4. Identify effectively the welding methods as used in pipes and pressure vessels welding
5. Apply effectively welding methods as used in pipes and pressure vessels welding process
6. Describe correctly the types of welds as applied in pipes and pressure vessels welding
7. Apply correctly the types of welds as required in pipes and pressure vessels welding
8. Apply properly finishing methods required in pipes and pressure vessels welding
9. Apply properly surface protection as required in pipes and pressure vessels welding
10. Describe clearly the weld defects as found in pipes and pressure vessels welding
11. Apply correctly testing techniques as used in pipes and pressure vessels welding
12. Correct properly weld defects as required in pipes and pressure vessels welding

Resources

Equipment	**Tools**	**Materials**
● MIG/MAG machine kit ● FCAW machine kit ● TIG machine kit ● Shielding gas cylinder ● Oxyacetylene kit ● Air compressor	● Steel rulers ● Tape measures ● Combination square ● Protractors ● Scriber ● Hack saw ● Files	● Pipes ● Sheet metal ● Plate metal ● MIG wire ● Shielding gas ● Filler rod ● FCAW wire ● Paint

- Spray gun - Angle grinder - Trolley - Welding table - Fume extractor	- Chisel - Centre punch - Table clamps - Gigs - Bench vices - Pipe vice - Hammers - Screwdrivers` - Cutting pliers - Wrenches - Soft brush - Painting roller - Cylinder key - Level	- Thinner - Papers - Wood - Discs - Sanding papers - Oil - Fuel - Masking tape - Water - Gas

Indicative content 3.1: Joining Pipes and Pressure Vessels

Duration: 40 hrs

Practical Activity 3.1.1: Joining pipes and pressure vessels

Task:

You are requested to go in manufacturing workshop and join pipes and pressure vessels as required in pipes and pressure vessels welding based on joining criteria.

1: Apply safety precautions.

2: Join pipes and pressure vessels as required in pipes and pressure vessels welding process

3: Present your work to the trainer and whole class.

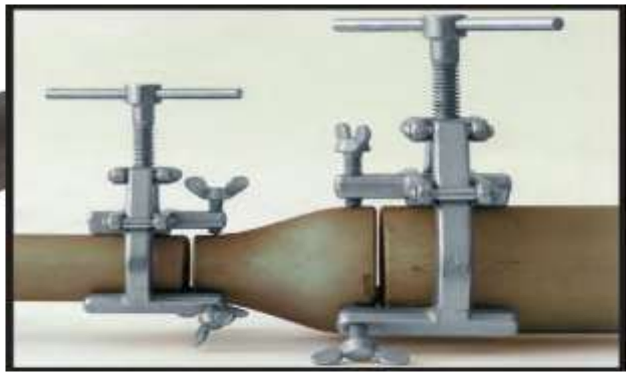
4: Read key reading 3.1.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 3.1.

Key readings 3.1.1: Joining pipes and pressure vessels

- **Aligning work pieces**

Aligning work pieces involves positioning multiple components or materials in a precise manner so that they fit together correctly during assembly or machining. This process is crucial in ensuring the accuracy and functionality of the final product. Proper alignment can prevent issues like uneven wear, misfitting parts, and operational failures.



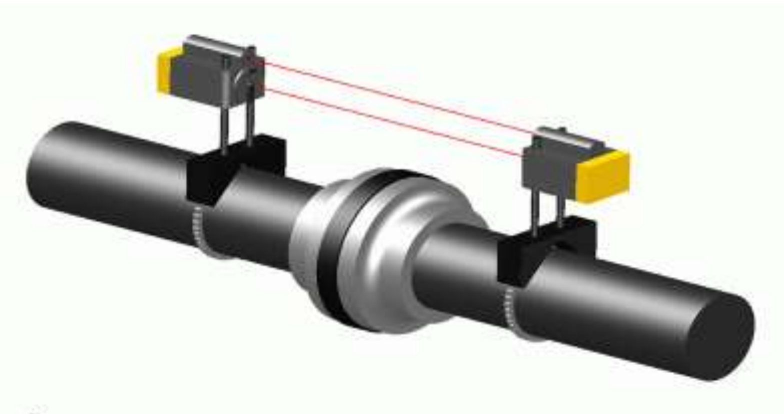
✓ **Alignment tools**

Alignment tools

Alignment tools are specialized instruments used to achieve precise positioning of work pieces. Some common tools include:

- **Dial indicators:** Dial indicators are precision measuring instruments used to measure small distances and detect deviations in alignment or displacement. They are commonly employed in machining, manufacturing, and quality control processes to ensure the accuracy of parts and assemblies.

- **Laser levels:** Laser levels are advanced tools that project a straight, level line of laser light across a surface, providing a highly accurate reference for various applications in construction, renovation, and alignment tasks. They are essential for ensuring that installations, such as shelves, tiles, and framing, are level and straight.



- **Straight edges:** Provide a flat reference surface to check alignment against. Engineer's straight edges are precision measuring devices used to check that surfaces are straight. Engineer's straight edges can take several forms; some look like rulers, others like spirit levels, rectangular pieces of stone or I-beam girders. But all will have at least one precision edge that is straight.

- **Alignment plates:** Flat, rigid surfaces used as reference points for checking alignment. Alignment plates are specialized tools used in various industrial applications to assist in the precise alignment of components, such as pipes, pressure vessels, machinery, and structural elements, before welding or assembly.

  Steps for using alignment plates

Step 1: Surface Preparation: Ensure that the alignment plates are clean and free of debris before use.

Step 2: Leveling: Confirm that the alignment plates are level to provide an accurate reference surface.

Step 3: Regular Inspection: Check the flatness and condition of alignment plates regularly to maintain their effectiveness.

Step 4: Secure Clamping: Use appropriate clamping techniques to hold the workpieces securely against the alignment plate.

✓ **Alignment methods**

- **Procedures for Aligning Pipes and Pressure Vessels**

✓ **Preparation**

–Remove contaminants (oil, rust, dirt) from the weld areas using appropriate cleaning methods (grinding, sandblasting, or chemical cleaners).

-Check for dimensional accuracy and tolerances using callipers, tape measures, or laser alignment tools.

✓ **Positioning**

-Place the pipes or pressure vessel components in their intended positions using cranes, forklifts, or other handling equipment.
-Use blocks, stands, or rollers to support the workpieces at strategic points, ensuring stability and access for welding.

✓ **Alignment techniques**

- **Visual inspection:**

-Look down the length of the pipes or across the pressure vessel surfaces to detect misalignment.

- **Using levels and squares:**

-Utilize spirit levels or squares to confirm that workpieces are level and properly aligned in all dimensions.

- **Pipe alignment tools:**

-For pipes, consider using alignment clamps or pipe jacks to adjust the positioning and eliminate gaps.

✓ **Tack welding**

- **Initial tack welds:**

-Perform tack welds at key locations to hold the workpieces in alignment. Tack welds should be placed at intervals to maintain alignment while allowing for adjustments.

- **Recheck alignment:**

-After tack welding, recheck the alignment to ensure no shifts occurred during the process.

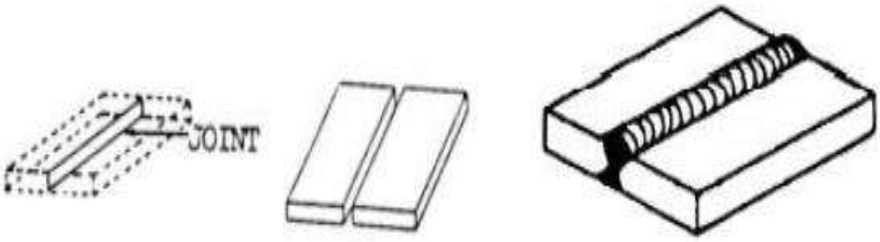
✓ **Final adjustments**

- **Gap measurement:**

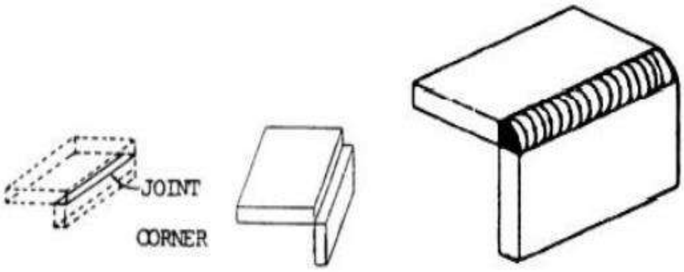
-Measure the gap between the workpieces with feeler gauges or callipers to ensure its within acceptable limits for the welding process.

- **Applying pipes and pressure vessels welding methods**
  - ✓ **Types of joints**

- **Butt joint:** It is a joint between two members aligned approximately in the same plane. This joint is frequently used in plate, sheet metal, and pipe work. A joint of this type may be either square or grooved. The sketch below shows the illustration of a Butt joint.

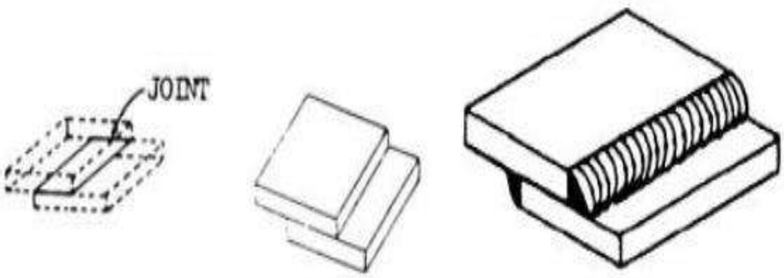


- **Corner joint:** It is a joint between two members located approximately at right angles to each other in the form of an L shape. Various joint designs of this type have uses in many types of metal structures. The sketch below shows the illustration of a corner joint.



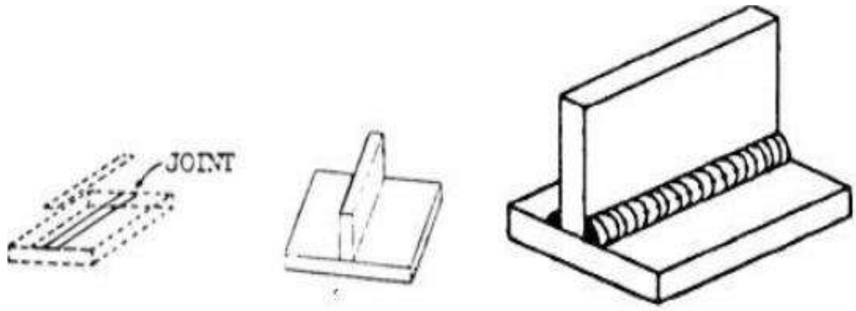
Corner joint

- **Lap joint:** It is a joint between two overlapping members. This is one of the strongest types of joints available; however, for maximum joint efficiency, you should overlap the metals a minimum of three times the thickness of the thinnest member you are joining. The sketch below shows the illustration of a lap joint.



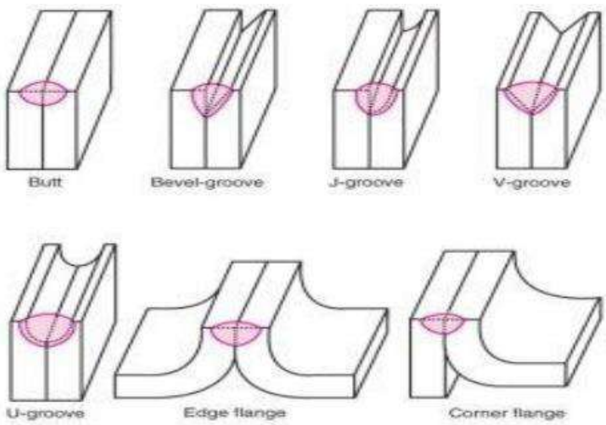
Lap joint

- **Tee joint:** It is a joint between two members located approximately at right angles to each other in the form of a T. Various joint designs of this type have uses in many types of metal structures. The sketch below shows the illustration of a Tee joint.



Tee joint

- **Edge welding joint:** Edge Joint. Edge welding Joints are often applied to sheet metal parts that have flanging edges or are placed at a location where a weld must be made to attach to adjacent pieces. Being a groove type weld, Edge Joints, the pieces are set side by side and welded on the same edge.



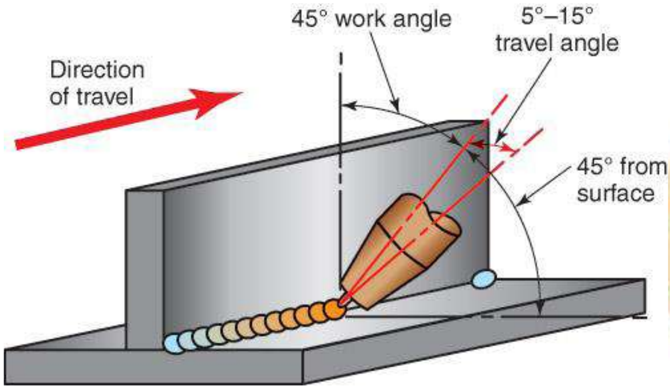
- ✓ **Welding positions**

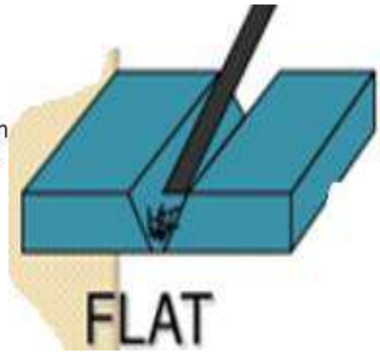
The welding position refers to the position of the welding operator towards the work piece to be welded. There are four basic welding positions, which are illustrated as below: All welding is done in one of four positions:

- **Flat or down-hand welding position**

The flat position or down hand position is one in which the welding is performed from the upper side of the joint and the face of the weld is approximately horizontal. This is the simplest and the most convenient position for welding. Using this technique, excellent welded joints at a fast speed with minimum risk of fatigue to the welders can be obtained. The symbol of this type is

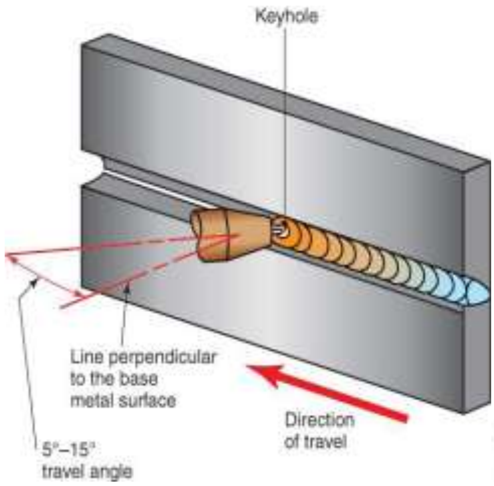
1 G (1 represent flat position and G represent groove weld) and **1F** (1 represent flat position and F represent fillet weld)





Horizontal welding position

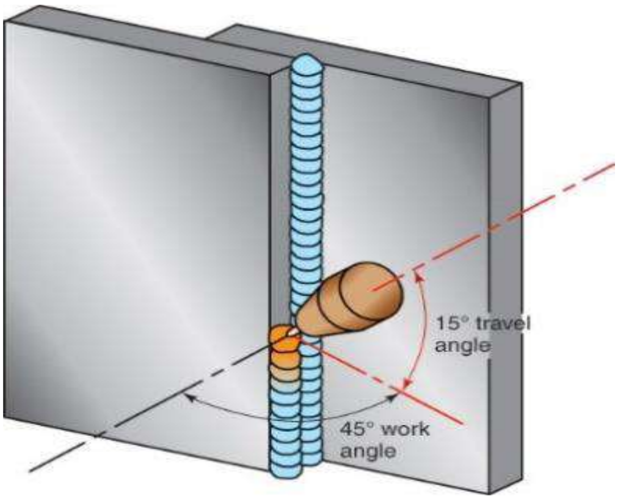
In horizontal position, the plane of the workpiece is vertical and the deposited weld head is horizontal. The metal deposition rate in horizontal welding is next to that achieved in flat or down hand welding position. This position of welding is most commonly used in welding vessels and reservoirs.



Vertical welding position

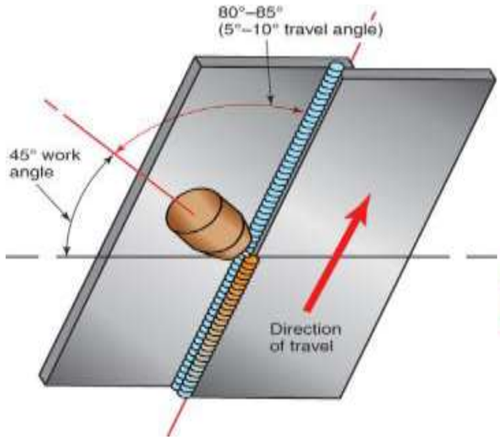
In vertical position, the plane of the workpiece is vertical and the weld is deposited upon a vertical surface. It is difficult to produce satisfactory welds in this position due to the effect of the force of gravity on the molten metal. The welder must constantly control the metal so that it does not run or drop from the weld.

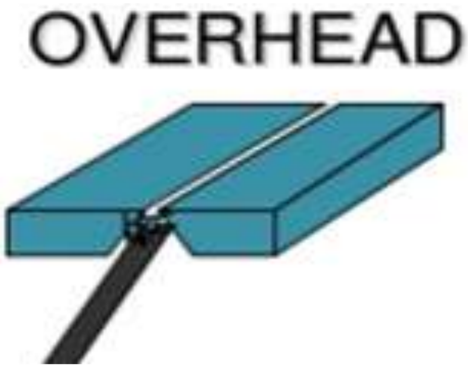
Vertical welding may be of two types viz., vertical-up and vertical-down. Vertical-up welding is preferred when strength is the major consideration. The vertical-down welding is used for a sealing operation and for welding sheet metal.



Overhead welding position

The overhead position is probably even more difficult to weld than the vertical position. Here the pull of gravity against the molten metal is much greater. The force of the flame against the weld serves to counteract the pull of gravity. In overhead position, the plane of the workpiece is horizontal. But the welding is carried out from the underside. The electrode is held with its welding end upward. It is a good practice to use very short arc and basic coated electrodes for overhead- welding.



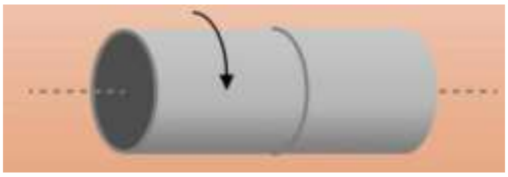


The types of welding positions are represented by letter symbols and number in welding symbols, here, **Groove** weld is indicated by letter **G,** while **Fillet** weld is indicated by letter **F.** therefore it may be either **1G** for flat position groove weld, **2G** for horizontal position groove weld, **3G** for vertical position groove weld and **4G** for overhead position and finally **5G** for welding pipes, or **1F** for flat position fillet welds, **2F** for horizontal, **3F** vertical and **4F** for overhead position Fillet weld respectively.

✓ **Pipe welding positions**

1G (Horizontal rolled position)

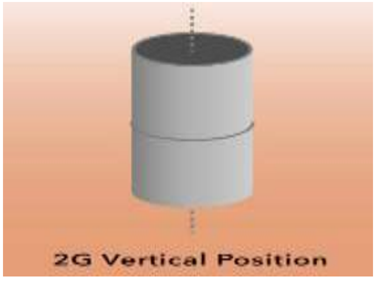
In the 1G welding position, the pipe is in the horizontal position and can be rotated along the horizontal (X) axis. The welder's position remains stationary. Welding is performed on the top of the pipe. This is the most basic welding position that can be performed.



(1G Horizontal rolled position)

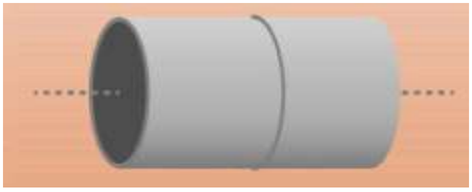
- **2G vertical position**

In the 2G welding position, the pipe is in the vertical position and can be rotated along the vertical (Y) axis. The welder's position remains stationary. Welding is performed on the side of the pipe in a horizontal direction.



- **5G horizontal fixed position**

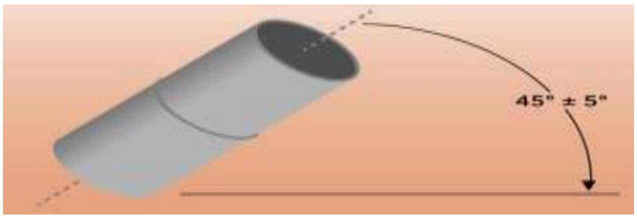
In the 5G welding position, the pipe is in the horizontal position. Unlike the 1G position, the pipe is in a fixed position and it cannot be rotated. The welder moves around the pipe in the vertical direction to perform the welding.



(5G horizontal fixed position)

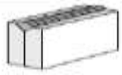
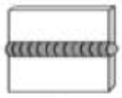
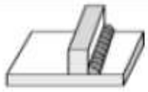
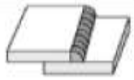
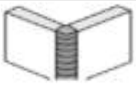
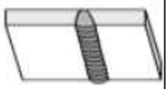
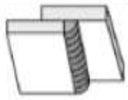
- **6G inclined position**

In the 6G welding position, the pipe slopes at approximately 45° from the horizontal (X) axis or 45° from the vertical (Y) axis. The pipe is in a fixed position, so the welder must move around the pipe to perform the welding. This is an advanced welding position that requires a great deal of experience and technical expertise.



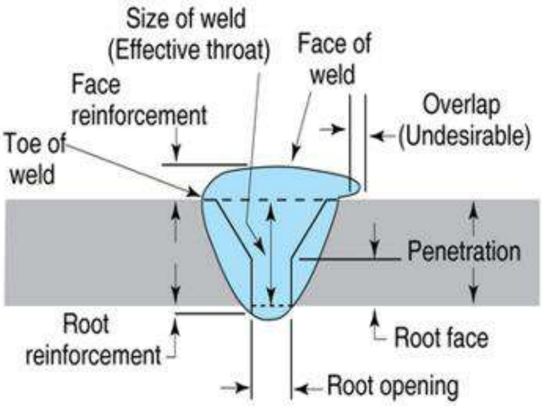
(6G inclined position)

Table below shows the various positions and joints used in plate welding.

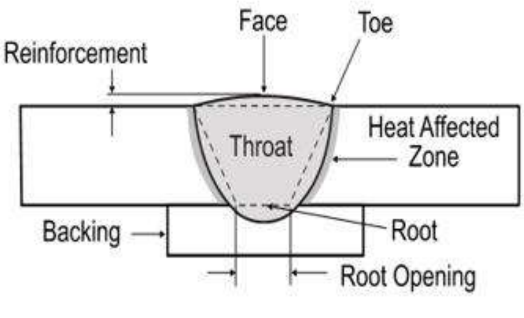
POSITION	JOINT				
	Butt Joint	Corner Joint	T – Joint	Lap Joint	Edge Joint
Flat					
Horizontal					
Vertical					
Overhead					

- ✓ **Types of welds**
- **Groove weld joint**

A weld groove is defined as "A channel in the surface of a work-piece or an opening between two joint members providing space to contain weld metal." Groove welds fill the space made between sections of the work-piece. AWS A3.0 defines nine (9) types of single groove welds and seven (7) types of double groove welds.

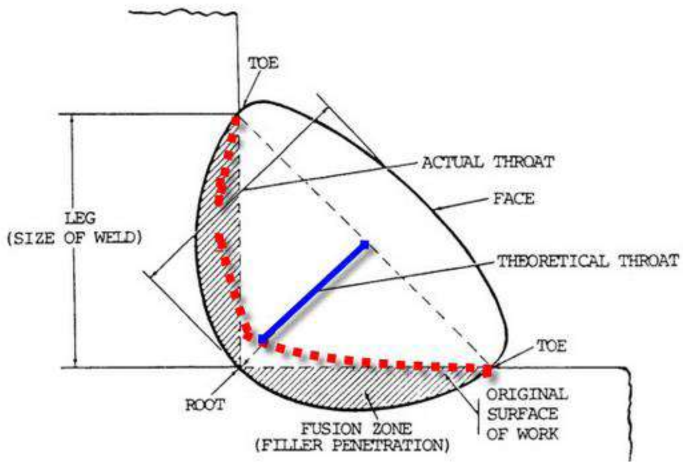


Groove Weld



Groove Weld Terminology

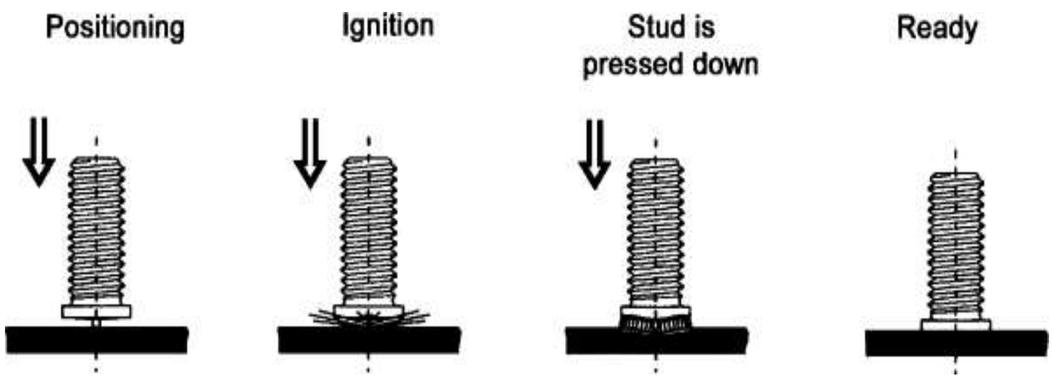
- **Fillet weld joint**



Fusion zone (Filler Penetration): The fusion zone is the area of base metal melted as determined in the cross section of a weld. Leg of a Fillet Weld: The leg of a fillet weld is the distance from the root of the joint to the toe of the fillet weld? There are two legs in a fillet weld.

1. **Root**: This is the point at which the bottom of the weld intersects the base metal surface, as shown in the cross section of weld.
2. **Size of the weld (Equal leg-length fillet welds):** The size of the weld is the depth of chamfering plus the root penetration when specified on grove weld.
3. **Face of the weld.** This is exposed surface of the weld, made by an arc or gas welding process on the side from which the welding was done.
4. **Toe of the weld:** is the junction between the face of the weld and the base metal.
5. **Reinforcement of the weld**: This is the weld metal on the face of a groove weld in excess of the metal necessary for the specified weld size.

Stud weld: Stud welding is a process used to join a metal stud or fastener to a workpiece using an arc. Stud welding is a process that involves welding a metal fastener to another metal part using an arc of electricity to heat both parts



Stud welding process:

- **Trigger the welding gun**: Once positioned, pull the trigger on the stud welding gun. This creates an electrical arc between the stud and the workpiece.
- **Arc creation**: The arc melts the end of the stud and the surface of the workpiece.
- **Stud insertion**: The stud is then pressed into the molten metal, fusing it with the base metal.
- **Cooling**: Allow the weld to cool and solidify, forming a strong joint between the stud and the workpiece.

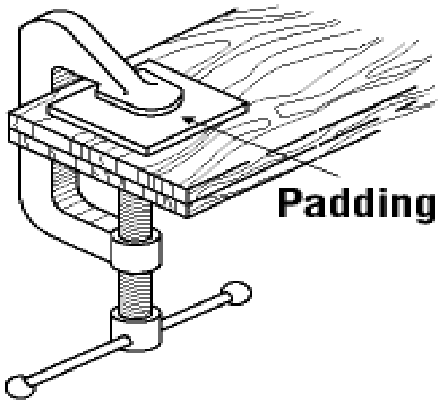
✓ **Work pieces positioning**

Before welding a workpiece, it is important to ensure that it is positioned correctly to ensure proper weld quality and avoid any potential safety hazards. The exact position of the workpiece will depend on the type of welding being performed, the thickness of the workpiece, and the desired weld joint.

1. For flat or horizontal welding, the workpiece should be positioned flat on a work surface with the joint to be welded facing upward.
2. For vertical welding, the workpiece should be positioned vertically with the joint to be welded facing outward.
3. For overhead welding, the workpiece should be positioned securely above the welder, with the joint to be welded facing downward.

Fixturing and positioning workpiece tools and equipment

- **Clamps:** These are used to hold the workpiece securely in place and prevent it from moving during welding. There are many different types of clamps available, such as C-clamps, bar clamps, and welding clamps.

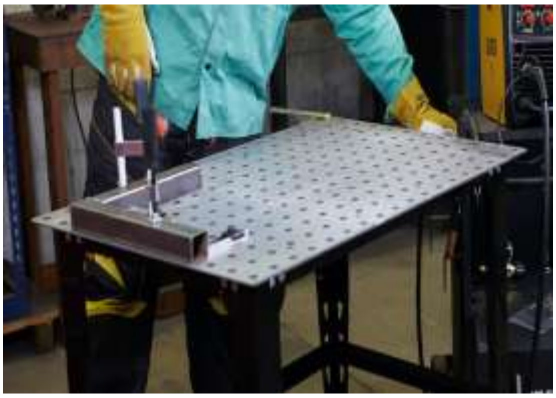


- **Magnetic holders:** These can be used to hold metal workpieces in place without the need for clamps. Magnetic holders are especially useful for flat or horizontal welding.


- **Welding jigs:** These are custom-made tools designed to hold workpieces in a specific position for welding. Welding jigs can be complex or simple, depending on the project's requirements.


- **Vises:** A bench vise is a tool that can be used to securely hold small workpieces in place while welding.
- **Tack welds:** Tack welds are temporary welds used to hold workpieces in place before the final weld is completed. They can be useful for complex projects that require precise positioning.

- **Welding tables:** Welding tables are flat surfaces designed specifically for welding projects. They often have built-in clamps and fixtures to hold workpieces securely in place.



- **Jack stands and support blocks:** These can be used to support large or heavy workpieces during welding to prevent them from sagging or warping.

Tack welds the pieces

Tack welding is a welding technique used to temporarily hold two or more pieces of metal together before a more permanent welding process is performed. Tack welds are small welds that are made at various points along the seam to be welded, and they are used to prevent the metal from shifting or moving during the welding process and ensures their alignment.

- **Alignment:** Alignment; A joint between two members aligned approximately in the same plane. Fillet weld; A weld of approximately triangular cross section joining two surfaces at approximately right angles to each other.

- **Regular gap:** Regular gap, Root gap are basically the small gap between pieces to be joined. During welding this small gap allows the liquid molten metal to pass through and fuse properly. It ensures proper penetration which determines the strength and durability of the welding joint.
- **Adjustment:** Adjustment; Slope in MIG welding is defined as the rate of drop in voltage as the amperage increases while welding. Some of the older and larger transformer welders did have limited slope adjustment, or special taps that would change the inductance of the welder.

Factors to be considered in tack welding

It is a weld made to hold parts of an assembly in proper alignment temporarily until the final welds are made. Although the sizes of tack welds are not specified, they are normally between 1/2 inch to 3/4 inch in length, but never more than 1 inch in length. In determining the size and number of tack welds for a specific job, you should consider thicknesses of the metals being joined and the complexity of the object being assembled.

- **Size of work pieces:** The size of a workpiece refers to the length of the legs of the weld. The two legs are assumed to be equal in size unless otherwise specified.
- **Types of material:** To produce welds that meet to the job required, it is important to know the type of material, it also helps to describe its mechanical properties.

Complete the full welding procedures

1. **MIG/MAG welding (Metal Inert Gas / Metal Active Gas)**

- Clean the base metal to remove rust, oil, or paint.
- Set up the welding machine and choose the correct wire diameter and gas type (inert gas for MIG, active gas for MAG).
- Load the wire into the feeder and adjust the speed.
- Set the gas flow rate (typically around 15-25 L/min).
- Adjust the voltage and current according to the material thickness.

- Hold the torch at a 10-15-degree angle from vertical.
- Maintain a consistent distance between the wire and the workpiece.
- Start welding by pulling the trigger and making smooth, steady movements.
- Inspect the weld for defects like spatter or lack of fusion.
- Clean the weld if necessary.

2. TIG welding (Tungsten Inert Gas)

- Clean the workpiece thoroughly (TIG is sensitive to contaminants).
- Select a tungsten electrode and grind the tip to a point.
- Set the gas flow (usually argon) to about 10-20 L/min.
- Set the current based on the thickness and type of material.
- Load the tungsten electrode into the torch.
- Choose filler metal if necessary.
- Hold the torch at a 70-80-degree angle to the workpiece.
- Start the arc with a foot pedal or high-frequency start.
- Add filler metal manually by dipping it into the weld pool.
- Allow the weld to cool naturally (do not force-cool).
- Inspect for any issues like undercut or porosity.

3. FCAW (Flux-Cored Arc Welding)

- Clean the workpiece to ensure no contaminants.
- Choose the appropriate flux-cored wire and adjust the machine settings accordingly.
- Set the wire speed and voltage based on the material thickness.
- Hold the torch at a 10-15-degree angle.
- Maintain a consistent distance between the wire and the workpiece.
- Move steadily, creating a uniform weld bead.
- Inspect the weld for slag, which can be chipped away.
- Check for any defects or inconsistencies in the weld.

Points to Remember

- Each welding methods requires specific tools and careful attention to technique to ensure a strong, clean weld.
- Clean the base metal to remove rust, oil, or paint. Ensure the surface is free of contaminants that could affect weld quality.
- Set up the welding machine, ensuring the correct wire diameter and gas type are selected (inert gas for MIG, active gas for MAG).

Application of learning 3.1.

Around your school, there is a broken stainless-steel pipe of 0.7m diameter and 10mm thick to be re-joining by welding. You are asked to join the broken pipe:

Indicative content 3.2: Finishing the Product

Duration: 5 hrs

Practical Activity 3.2.1: Finishing the product

Task:

You are requested to go in manufacturing workshop and apply finishing to the welded products as required in pipes and pressure vessels welding based on finishing techniques.

1: Apply safety precautions.

2: Finish the product as required in pipes and pressure vessels welding process

3: Present your work to the trainer and whole class.

4: Read key reading 3.2.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 3.2.

Key readings 3.2.1: Finishing the product

- **Finishing the product**

✓ **Finishing techniques**

- **Grinding:** Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool to remove some amount of material on a given workpieces in order to obtain the desired sizes and shape of the finished product

✓ **Steps for grinding a welded product**

- Before beginning, inspect the weld visually to identify rough areas, spatter, or excessive material. Ensure the weld is structurally sound before grinding to avoid weakening it through excessive material removal.

- Select the right tool based on the material type and size of the weld. Common tools include:
- Choose the correct grit size for the grinding disc or flap disc. Lower grit (coarse) is ideal for heavy material removal, while higher grit (fine) is better for smooth finishing. Example: 40-60 grit for rough grinding, 80-120 grit for finishing.
- Ensure the workspace is clean and well-ventilated. Wear appropriate personal protective equipment (PPE), including safety goggles, gloves, ear protection, and a face shield.
- Secure the welded product on a stable surface, such as a workbench or vise. Ensure it is positioned to allow easy access to the weld for smooth, consistent grinding.
- Start grinding along the weld bead, applying consistent pressure. Move the grinder in a steady, back-and-forth motion, working along the entire length of the weld. Keep the grinder at a 10° to 15° angle to prevent gouging the surface.
- Avoid staying in one spot for too long, as this can overheat the metal and cause damage.
- Periodically stop and check the progress to ensure that you're not removing too much material and that the surface is becoming smooth and even. Adjust the angle or pressure as needed to achieve the desired result.
- After grinding, inspect the weld area again to ensure it is smooth and free from imperfections like pitting, gouges, or spatter. If necessary, perform additional light grinding or polishing for a flawless finish.
- Clean the welded and ground surface with a brush or compressed air to remove any debris or dust. You can also use a degreaser or solvent if needed to prepare the surface for painting or coating.

- **Sanding:** Sanding is the process of cleaning materials especially metals by using sand papers as shown in figure below;

- **Brushing:** Is a process of removing some amount of material on a given workpieces by using wire brush in order to obtain the desired sizes and shape of the finished product. Steel wire brushes are a tool fabricator use to finish different types of metals. Brushes are used to remove flaking paint, rust, scratches, dirt and small imperfections. They are used on concrete, metal, stone and wood surfaces. Wire brush attachments are made for drills, grinders and other types of fabrication tools.

- **Polishing**: Is an abrading process in which small amounts of metal are removed to produce a smooth or glossy surface by application of cushion wheels impregnated or coated with abrasives. Polishing may be used for reduction or smoothing of the surface to a common level for high finish where accuracy is not important or it may be employed for removing relatively large amounts of material from parts of irregular contour.

✓ **Applying surface protection techniques**

Surface protection techniques are essential to prevent corrosion, wear, and damage to metal surfaces. The two common methods include coating and oiling/lubricating, both of which provide a protective barrier between the metal and its environment.

- **Types of coatings**

Coating involves applying a protective layer over the metal surface to shield it from corrosion, oxidation, and environmental damage.

- **Paint:** One of the most common methods, applying paint helps prevent rust and corrosion. It forms a barrier that prevents oxygen and moisture from reaching the metal.
- **Powder coating:** A dry powder is applied electrostatically and then cured under heat to create a hard, durable finish. This method offers excellent protection and aesthetics.
- **Galvanization:** A process where steel or iron is coated with zinc to protect it from corrosion. The zinc layer acts as a sacrificial layer that corrodes before the base metal.
- **Epoxy coating:** A tough, chemically resistant coating that provides high durability, especially in harsh industrial environments.

- **Procedure for applying coating**

- Clean the metal surface by removing any rust, dust, or oil using methods like sandblasting, grinding, or chemical cleaning.

- Ensure the surface is smooth and free from imperfections.
- Apply a primer coat to improve adhesion and add an extra layer of protection, especially for paint or powder coatings.
- For paint, use brushes, rollers, or spray guns to apply an even layer over the metal surface.
- For powder coating, use an electrostatic gun to spray the powder and then bake the metal to cure the powder.
- For galvanizing, the metal is dipped in a molten zinc bath.
- Allow the coating to cure or dry completely before handling or using the part.
- Inspect the surface to ensure the coating is uniform and free of defects like bubbles or streaks.

Benefits of oiling/lubricating

Oiling or lubricating involves applying oil or lubricants to metal surfaces to protect them from corrosion, wear, and friction.

- **Corrosion protection:** Oils act as a barrier between the metal surface and moisture, preventing rust and oxidation.
- **Lubrication:** Reduces friction between moving parts, prolonging the life of components by minimizing wear.
- **Temporary protection:** Often used for temporary protection of metal parts during storage or transport.

Procedure for applying oiling/lubricating

- Clean the metal surface to remove dirt, debris, or old oils using a degreaser or solvent.
- Ensure the surface is dry before applying oil or lubricant.
- Choose an appropriate type of oil based on the material and application, such as machine oil, cutting oil, or anti-corrosion oils.
- Use a cloth, brush, or spray bottle to evenly distribute the oil or lubricant across the surface.
- For moving parts, ensure the oil penetrates into joints, bearings, or gears.
- Wipe off any excess oil to prevent build-up, which can attract dirt and dust.
- Regularly inspect the surface to ensure the oil remains intact and reapply as needed, especially after use or exposure to moisture.

Points to Remember

- While selecting surface protection method depends on the application, environment, and duration of protection required.
- Before applying any coating, thoroughly clean the metal surface to remove rust, grease, and contaminants, this will improve the adhesion of the coating and increase its lifespan.

Application of learning 3.2.

In your school manufacturing workshop, there is a welded steel cylindrical pressure vessel of $6m^3$ to be finishing. You are asked to finish the welded product.

Indicative content 3.3: Testing the Product

Duration: 5 hrs

Practical Activity 3.3.1: Testing the product

Task:

You are requested to go in manufacturing workshop and test the welded products as required in pipes and pressure vessels welding based on testing criteria.

1: Apply safety precautions.

2: Teste the product as required in pipes and pressure vessels welding process

3: Present your work to the trainer and whole class.

4: Read key reading 3.3.1 and ask clarification where necessary.

5: Perform the task provided in application of learning 3.3.

Key readings 3.3.1: Testing the product

- **Testing the product**
  - ✓ **Applying testing techniques**

Visual inspection

This is the simplest form of testing where a trained inspector examines the weld using the naked eye or magnification tools. The inspector looks for visible defects like cracks, undercuts, porosity, misalignment, or weld size inconsistencies. It's typically the first step before more advanced testing methods are applied.

Hydrostatic testing

In this test, the welded product is filled with water (or another liquid) and pressurized to a specified level to check for leaks, structural integrity, or potential failure. It's often used for pipelines, boilers, and pressure vessels to ensure that the welds can withstand the required pressure without leaking or bursting.

Pneumatic testing

This method is similar to hydrostatic testing, but instead of water, air or another gas is used. The product is pressurized with gas and checked for leaks. Because gases are compressible and can be more dangerous due to the high energy they store, pneumatic testing requires stricter safety precautions.

Dye penetrant testing

In this non-destructive test, a liquid dye is applied to the weld's surface. After a period of time, the excess dye is wiped off, and a developer is applied to draw out any dye that may have seeped into cracks or flaws. If there are defects like cracks or porosity, the dye will show up on the surface, indicating the location of the defect.

Radiographic testing

This method uses X-rays or gamma rays to inspect the internal structure of a welded product. The radiation penetrates the material and exposes a photographic film or detector placed behind the weld. The resulting image reveals internal defects, such as voids, cracks, or inclusions, that aren't visible on the surface.

- **Audio-graphic testing**

This lesser-known method involves using sound waves to detect defects in the weld. An instrument generates sound waves, which pass through the material. If there is a discontinuity or defect, the sound wave pattern will change, indicating a problem. This technique is related to ultrasonic testing, though it's less commonly used in standard welding tests.

✓ **Defect, causes and their remedies**

Welding defects can be defined as weld surface irregularities, discontinuities, imperfections, or inconsistencies that occur in welded parts.

- **Cracks:** Cracks are the worst welding defect since they can rapidly progress to larger ones, which inevitably leads to failure. Weld cracks are mainly classified depending on how they form in the weld bead. Longitudinal cracks form parallel to the weld bead while transverse cracks form across the width. Crater cracks form at the end of the bead, where the arc concludes.

Causes

- Using hydrogen shielding gas in welding ferrous metals.
- Ductile base metal and the application of residual stress.
- Rigid joints that constrain the expansion and contraction of the metal.
- Use of high levels of sulphur and carbon.

Prevention

- Preheating the metals and gradually cooling the weld joints.
- Maintaining acceptable weld joint gaps.
- Selection of the correct welding materials.

- **Porosity:** Porosity is the formation of holes in the weld pool resulting from gas bubbles that cannot escape. It is usually one of the common welding defects when using shielding gas, which is present in welding techniques such as TIG and stick welding. Absence, lack, or too much shielding gas may lead to metal contamination, which reduces the strength of the weld.

Causes

- Unclean welding surface.
- Wrong electrode selection.
- Lack or absence of shielding gas.
- Mishandled or damaged shielding gas cylinder.
- Either too low or too high welding current.
- Fast travel speed.

Prevention

- Cleaning the weld surface.
- Using the correct welding electrode.
- Preheating the metals before welding.
- Proper gas flow rate setting to achieve the right amount of shielding.
- Regularly checking for moisture contamination in the shielding gas cylinder.
- Adjustment of welding current and travel speed settings.

- **Undercut:** An undercut can be formed in various ways but mainly it is tied to two reasons. The first is using excessive current – the edges of the joint melt and drain into the weld. The second reason is not that enough filler metal is deposited into the weld. This results in a reduced cross-section meaning that there are notches or grooves along the weld, which increase stress when the material is subjected to fatigue loading. This defect occurs at the toe of the weld or in the case of multi-run welds, in the fusion face. An undercut may come from continuous, intermediate, and inter-run.

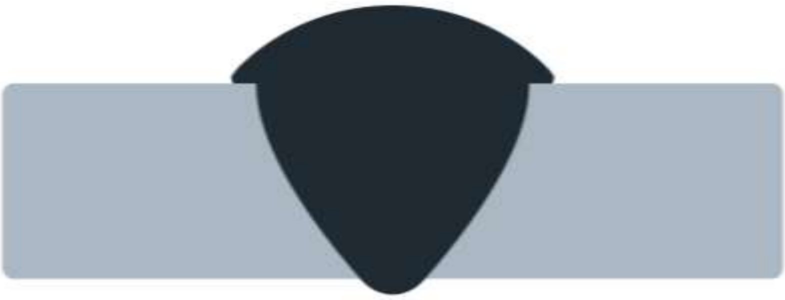
Causes

- High arc voltage.
- Incorrect electrode selection or wrong electrode angle.
- High travel speed.

Prevention

- Smaller arc length, voltage, and travel speed.
- 30 to 45-degree electrode angle.
- Reducing the electrode diameter.

- **Overlap:** Is the excess metal that spreads out around the bead. The spread-out filler metal is not properly mixed with the base metals. Typically, it comes in a round shape over the weld joint.



Causes

- Incorrect welding procedure.
- Wrong selection of welding materials.
- Improper preparation of base metals.

Prevention

- Smaller welding current.
- Use of proper welding techniques.
- Shorter welding electrode.

- **Burn-through:** An open hole is exposed when the welding process accidentally penetrates the whole thickness of the base metal, creating a burn-through or melt-through. This is one of the common weld defects when welding thin metals.

Causes

- High welding current.
- Extreme gap to the root.
- Not enough root face metal.

Prevention

- Maintaining a proper root gap.
- Control in the application of welding current.
- It can be repaired in some cases wherein the hole is removed and re-welded.

- **Spatter:** Spatter is a welding defect that occurs when metal droplets are discharged on the metal surface. It solidifies and becomes stuck on the metal surface once it cools down. In most cases, spatter does not alter the structural integrity of the weld but generally, it has to be removed, adding to the total costs.

Causes

- High arc length.
- High welding current.
- Improper shielding of the heat-affected zone.
- Using the wrong polarity may create excessive spatter.

Prevention

- Choosing the correct weld polarity.
- Selecting a better shielding gas and better shielding technique.
- Reducing the welding current and arc length to optimal condition.
- **Under filled:** Underfill occurs when too little weld metal is deposited into the joint. As a result, some of the parent material remains unfused and the joint is under filled. These unfused sections, even when small, act as potential stress raisers.

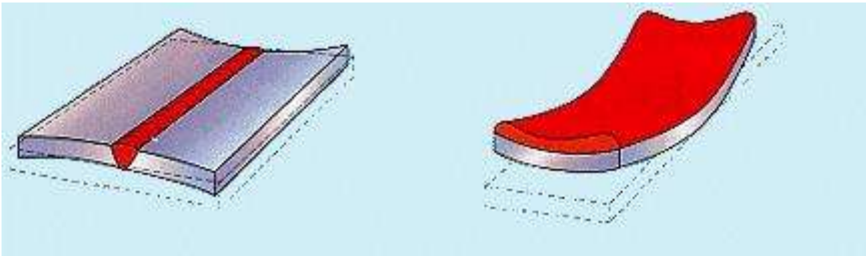
Causes

- Low welding current.
- Too high travel speeds.
- Incorrect weld bead placement.
- Laying weld beads too thinly in multi-pass welds.

Prevention

- Proper electrode size selection.
- Selecting the right current setting.
- Avoid moving too fast.

- **Distortion:** Distortion or warping is an accidental change in the shape of the surrounding metal of the weld. Excessive heating around the weld joint is the main reason for distortion around its area. Warpage or distortion mostly occurs in thin metals and is classified into four types: angular, longitudinal, fillet, and neutral axis.



Causes

- Thin weld metal.
- Incompatible base metal and weld metal.
- High amount of weld passes.

Prevention

- Using suitable weld metals.
- Optimising the number of weld passes.
- Selection of better welding methods for the metal type.

- **Slag inclusion:** A weld bead that contains slag in its composition compromises the toughness and structure of the metal. Slag inclusion may occur either on just the surface of the weld metal or in between welding cycles. This weld defect is common to processes that use flux, such as stick, flux-cored, submerged arc welding, and brazing.

Causes

- Incorrect welding angle and travel speed of the welding torch.
- Poor pre-cleaning of the edge of the weld surface.
- Low welding current density resulting in inadequate heating of the metals.

Prevention

- Higher welding current density.
- Optimal welding angle and travel speed to avoid slag inclusion in the weld pool.
- Consistent weld edge cleaning and slag removal of each layer.

- **Incomplete Fusion:** Incomplete fusion results from poor welding wherein the metals pre-solidify, forming gaps in the weld zone. When the welder cannot properly melt the parent metal with the base metal, it results in a lack of fusion.

Causes

- Low heat input resulting in metals not melting.
- Wrong joint angle, torch angle, and bead position.
- Extremely large weld pool.

Prevention

- Higher welding current and slower travel rate to ensure the melting process of the metals.
- Improving welding positions such as joint angle, torch angle, and bead position.
- Lower deposition rate.

- **Incomplete Penetration:** Incomplete penetration generally occurs during butt welding, wherein the gap between the metals isn't filled completely through the joint thickness. This means that one side of the joint is not fused in the root.

- Incorrect use of the welding technique.
- Wrong electrode size.
- Low deposition rate.

Prevention

- Using the correct welding technique and procedure.
- Higher deposition rate.
- Proper electrode size selection.

✓ **Correcting welding defects**

- **General correction techniques**

- **Grinding:** Use grinding tools to remove surface defects like cracks, slag inclusion, spatter, or undercuts before re-welding.
- **Preheating and post-heating:** Use controlled heating before and after welding to reduce thermal stresses and prevent cracks or distortion.
- **Re-welding:** After the defect is removed (e.g., by grinding or gouging), re-weld the joint using corrected welding parameters.
- **Surface cleaning:** Ensure the workpiece is clean and free of contaminants before and during welding to avoid defects like porosity and slag inclusion.
- **Visual and NDT inspection:** Use visual and non-destructive testing (NDT) techniques such as ultrasonic or radiographic testing to identify hidden defects

before performing corrections.

Practical Activity 3.3.2: Correcting the weld defects

Task:

You are requested to go in manufacturing workshop and test the welded products as required in pipes and pressure vessels welding based on testing criteria.

1: Apply safety precautions.

2: correct the product as required in pipes and pressure vessels welding process

3: Present your work to the trainer and whole class.

4: Read key reading 3.3.2 and ask clarification where necessary.

5: Perform the task provided in application of learning 3.3.

Key readings 3.3.2: Correcting the weld defects

- **Correcting Welding Defects**

Welding defects can occur due to improper technique, incorrect parameters, or material issues. Correcting these defects is crucial to ensure the weld's strength, integrity, and appearance. Below are some common welding defects and how to correct them:

✓ **Porosity:** Small holes or cavities in the weld caused by trapped gas.
Correction:
- Grind out the affected area and re-weld.
- Ensure proper shielding gas coverage and clean the surface before welding to prevent contamination.
- Adjust the welding parameters to reduce spatter and gas entrapment.

✓ **Undercut:** A groove at the base of the weld that weakens the joint.
Correction:
- Grind or fill the undercut area with a new weld bead.
- Adjust the welding speed and reduce the current to avoid excessive melting at the edges.
- Use proper electrode angles to maintain even heat distribution.

✓ **Cracks**: Visible or internal fractures in the weld, caused by improper cooling or material stress.
Correction:

- Grind out the entire crack and re-weld with appropriate preheat and post-weld heat treatment if necessary.
- Use a proper filler material and ensure slow, even cooling.
- Avoid excessive stress on the weld by using appropriate joint design and welding techniques.

✓ **Lack of Fusion**: Incomplete melting between the weld metal and the base metal.

Correction:

- Grind out the affected area and re-weld, ensuring a proper arc length and correct electrode positioning.
- Increase the welding current or use a different welding process to ensure full penetration.
- Clean the base material to remove contaminants that could prevent fusion.

✓ **Incomplete Penetration:** The weld metal does not penetrate the joint thickness, resulting in a weak weld.

Correction:

- Grind out the insufficiently penetrated area and re-weld with a higher amperage or slower weld speed.
- Ensure proper joint preparation (e.g., gap size, beveling) to allow for full penetration.
- Use multiple passes for thicker materials.

✓ **Slag Inclusions:** Non-metallic material trapped in the weld metal, often from flux.

Correction:

- Chip, grind, or gouge out the slag inclusion and re-weld.
- Ensure thorough cleaning between passes and use the correct electrode angle to prevent slag trapping.
- Adjust the welding speed to allow proper slag removal.

✓ **Excessive Spatter**: Small molten metal droplets that stick to the base material around the weld.

Correction:

- Clean up spatter using a grinder or chipping hammer.
- Adjust voltage, amperage, and shielding gas to minimize spatter formation.
- Ensure proper electrode angle and distance.

✓ **Distortion:** Warping or bending of the material due to uneven heat distribution.

Correction:

- Use a clamping device or pre-bend the material to control distortion.
- Apply heat evenly across the weld area and use shorter welds to reduce heat input.
- Perform post-weld heat treatment or mechanical straightening if needed.

Points to Remember

- Maintain a record of all defects, including their types and frequencies. This data can help in trend analysis and future corrections.
- Conduct periodic audits of welding processes and equipment to ensure compliance with established procedures and standards.
- Establish clear quality control guidelines for welds, including acceptable limits for defects. Ensure all welds meet these standards before final approval.
- Before welding, thoroughly clean the base material to remove contaminants like oil, rust, and moisture, which can cause defects like porosity and lack of fusion.
- Ensure proper gap size, bevelling, and fit-up to allow full penetration, especially for thicker materials.

Application of learning 3.3.

In your school manufacturing workshop, there is a welded steel cylindrical pressure vessel of $6m^3$ to be testing the defects and correcting them for use. You are asked to test the welded product and correcting the weld defects.

Learning outcome 3 end assessment

Written assessment

Q1**.** Read the following statement and re-write the letter corresponding to the correct answer

i. Which of the following is a precision measuring tool used to detect deviations in alignment?

A) Spirit level

B) Dial indicator

C) Laser level

D) Welding clamp

ii. Which joint is formed when two metal pieces overlap?

A) Butt joint

B) Corner joint

C) Lap joint

D) Tee joint

iii. In which welding position does the welder perform welding from the upper side of the joint?

A) Vertical position

B) Horizontal position

C) Flat position

D) Overhead position

iv. Which welding process uses an electrical arc to join a metal stud to a workpiece?

A) MIG welding

B) TIG welding

C) Stud welding

D) FCAW welding

v. Which coating process involves applying a protective zinc layer to steel or iron to prevent corrosion?
a) Epoxy coating
b) Galvanization
c) Powder coating
d) Painting

vi. Which testing method uses water or another liquid to pressurize the welded product and check for leaks?
a) Dye penetrant testing
b) Hydrostatic testing
c) Pneumatic testing
d) Radiographic testing

Q2. Read the following statement and answer by TRUE if it is correct or FALSE if it is incorrect.

a) Tack welding is a permanent weld used to hold pieces together during final welding.
b) A 2G welding position means the pipe is in a vertical position, and welding is performed horizontally on the side of the pipe.
c) Alignment plates are primarily used to clean the surfaces of workpieces before welding.
d) MIG welding uses an active gas like argon for welding.
e) Grinding should be done with consistent pressure and the grinder held at an angle to avoid gouging the metal surface.
f) Applying oil to metal surfaces provides temporary corrosion protection during storage or transport.
g) Burn-through occurs when excessive welding current penetrates the entire thickness of the base metal.
h) Incomplete penetration results in a lack of fusion between the weld pool and the base metal.

Q3. Read the following sentence and complete the blank space with **(pipe, overhead, corner, butt, 12 and 18, 15 and 25, radiographic)**

a) In the _________ welding position, the welding is carried out from the underside of the horizontal plane of the workpiece.
b) ______ joints are used when two metal pieces are joined at right angles in an L-shape.

c) In MIG welding, the recommended gas flow rate is typically between ______ and ______ litters per minute.

d) _______ testing uses X-rays or gamma rays to detect internal weld defects like cracks or voids.

Q4. Table below contain finishing techniques and their descriptions, match finishing techniques column to description column and provide the answer in provided space.

Answer	**Description**	**Finishing techniques**
A=….	a) Abrasive process using sandpaper to smooth or clean a surface.	**1.** Grinding
B=……	b) Process of using cushion wheels coated with abrasives to create a smooth finish.	**2.** Sanding
C=…..	c) Uses a grinding wheel to remove material to achieve the desired shape.	**3.** Bolting
D=…..	d) Process using wire brushes to clean and remove rust or imperfections.	**4.** Polishing
		5. Brushing

Practical assessment

AB is a metal product assembling company, located in MUSANZE district. They have received a tender of fabricating fuel pressure vessel of $100m^3$ made in stainless steel with inlet and out let pipes, but there is no specialized worker for pipes and pressure vessels welding. Suppose that you are hired for the described task, you are asked to:

1. Join pipes and pressures vessels
2. Finish the welded product
3. Test the welded product

References

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