# MECHANICS LEVEL – I

## Based on March 2021, Curriculum Version 1

## Module Title: - Routine Metal Arc Welding

## Module code: IND MCS1 M10 1221

## Nominal duration: 65Hours

Prepared by: Ministry of Labor and Skill

August, 2022

Addis Ababa, Ethiopia

## Table of Contents

# ACKNOWLEDGMENT

Ministry of Labor and Skills wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this Teaching, Training and Learning Materials (TTLM).

# ACRONYM

MMAW_Manual Metal Arc Welding

ASME_American Society of Mechanical Engineers

TTLM_Trainees Training Learning Materials

PPE_Personal Protective Equipment

ASFM_American Society Foresting and Materials

# Introduction to the Module

In this module, we are primarily concerned with in the fundamental working principles of routine metal arc welding process work welding requirement and typical items of arc-welding equipment and tools, rather than the specific types. For specific information about the equipment in the working station has to available, you should consult the manufacturer's instruction manual.

This module is designed to meet the industry requirement under the mechanics occupational standard, particularly for the unit of competency: Routine Metal Arc Welding.

**This module covers the units:**

- Requirement of arc welding process
- Welding Practices and principles
- Quality assurance and clean up in welding process

**Learning Objective of the Module**

- Identify the basic requirements of welding process
- Perform welding practices and principles
- Apply the quality assuranceand clean up

**Module Instruction**

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise.

## Unit one: Preparation of welding work

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Requirement of arc welding process
- Welding materials and equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify the arc welding requirements
- Select the proper welding materials and equipment.

## 1.1. Requirement of arc welding process

### 1.1.1. Concept of welding

"Welding is the process of joining together two pieces of metal so that bonding takes place at their original boundary surfaces". When two parts to be joined are melted together, heat or pressure or both is applied and with or without added metal for formation of metallic bond. The arc is struck between the electrode and the metal. It then heats the metal to a melting point. The electrode is then removed, breaking the arc between the electrode and the metal. This allows the molten metal to “freeze” or solidify. The arc is like a flame of intense heat that is generated as the electrical current passes through a highly resistant air gap. There are various welding processes but commonly used types include the following:

- SMAW (Shielded Metal Arc Welding)
- GMAW (Gas Metal Arc Welding)
- GTAW (Gas Tungsten Arc Welding)

In this level, SMAW/MMAW or Routine Arc Welding Process is to be discussed.

#### 1.1.2. Welding terminology

- Electrode: a rod that is used in arc welding to carry a current through a work piece to fuse two pieces together. In some welding processes, the electrode may also act as the filler metal.
- Filler metal: metal deposited into the weld to add strength and mass to the welded joint.
- Flux: a chemical cleaning agent that is applied to a joint just prior to the welding process to clean and protect the metal surface from surface oxides that form as a result of heating.
- Porosity: the appearance of tiny bubbles on a weld bead as a result of gas entrapment; excessive porosity can weaken a weld.
- Root opening: the separation at the joint root between the base metals.
- Shielding Gas: inert or semi-inert gas that is used to protect the weld puddle and arc from reacting negatively with the atmosphere.
- Slag: cooled flux that forms over the top of the weld; slag protects the cooling metal and is then chipped off.
- Spatter: liquid metal droplets expelled from the welding process.
- Weld ability: the ability of a material to be welded under prescribed conditions and to performas intended.

- Bead: the weld/deposited melted metal
- Ripple: Shape of the bead
- Pass: Each layer of the weld bead deposited
- Crater: Depression in the base metal
- Penetration: Depth of fusion with metal
- Arc Length: Distance from electrode to metal
- Weld Face: Exposed surface of weld
- Root: Base of weld
- Toe: Where the face meets metal
- Leg: Distance between toe and root
- Porosity: Voids of gas pockets in the weld
- Post-Heating: Heating after welding
- Pre-Heating: Heating before welding
- Spatter: Metal particles expelled during welding
- Weaving: Back and forth movement
- Undercut: Toe below metal surface
- Overlap: Toe above metal surface

### 1.1.3. Manual metal arc welding (MMAW)

MMAW is a welding process that creates an electric arc between a hand held, flux-coated, consumable filler wire and the work piece. Welding commences when an electric arc is struck by making contact between the tip of the electrode and the work. The intense heat of the arc melts the tip of the electrode and the surface of the work close to the arc. Tiny globules of molten metal rapidly form on the tip of the electrode, then transfer through the arc stream into the molten weld pool. In this manner, filler metal is deposited as the electrode is progressively consumed. The arc is moved over the work at an appropriate arc length and travel speed, melting and fusing a portion of the base metal and continuously adding filler metal. Since the arc is one of the hottest of the commercial sources of heat [temperatures above 9000° F (5000° C) have been measured at its center], melting of the base metal takes place almost instantaneously upon arc initiation. If welds are made in either the flat or the horizontal position, metal transfer is induced by the force of gravity, gas expansion, electric and electromagnetic forces, and surface tension. For welds in other positions, gravity works against the other forces. The flux coating breaks down in the arc to produce a gaseous shield that excludes atmospheric gases from the weld zone. The flux coating also provides a de-oxidizing action and forms a slag on the cooling weld. The MMAW welding process needs a suitable and constant current power source (AC or DC), a work piece, a work clamp, leads and flux-covered consumable electrodes. No shielding gas is used in manual metal arc welding. The coated melting electrode forms a shielding gas to protect the smelt and supplies additives to create the required seam. Manual metal arc welding can be used on nearly all materials suitable for welding, simply and efficiently. Shielding gas is not supplied but is created depending on the requirement and material when the electrode sheath melts. The procedure is also used in small and medium-sized businesses and when building ships, pipelines as well as steel constructions and bridges outdoors.

### 1.1.4. Application of Manual metal arc welding (MMAW)

This also referred to as "Stick Welding" is the most commonly used type of welding and used for everything from pipeline welding, farm repair and complex fabrication. It uses a "stick" shaped electrode and thus its name indicates. Materials that can be welded by this process include: steel, cast iron, stainless steel, etc, this process can also hard face with correct electrode.All welding processes depend on three main requirements for their operation. These are

- A heat or energy source – needed for fusion.
- Atmospheric shielding – to prevent oxygen and nitrogen in the atmosphere from contaminating the weld.
- Filler metal – to provide the required weld build-up.

### 1.1.5. General working principle of MMAW

The electrode is placed in an electrode holder, which is connected to one lug of a constant current welding power supply. This power supply can be operated on alternating current (AC),direct current electrode positive (DCEP), or direct current electrode negative (DCEN) depending on the type of electrode being used. A cable connected to the work is attached to the other lug. The machine is energized and the electrode is lightly touched to the work the arc is then initiated. The welder then manually moves the electrode along the weld joint. Thus, an electric arc will be created because of the resistivity of the air gap between metallic pieces what we are going to join. This arc causes the pieces to melt and join together. The flux cover of the electrode induces shielding gases and forms a slag on the top of the weld that are important to protect the weld from exposure to oxidation.

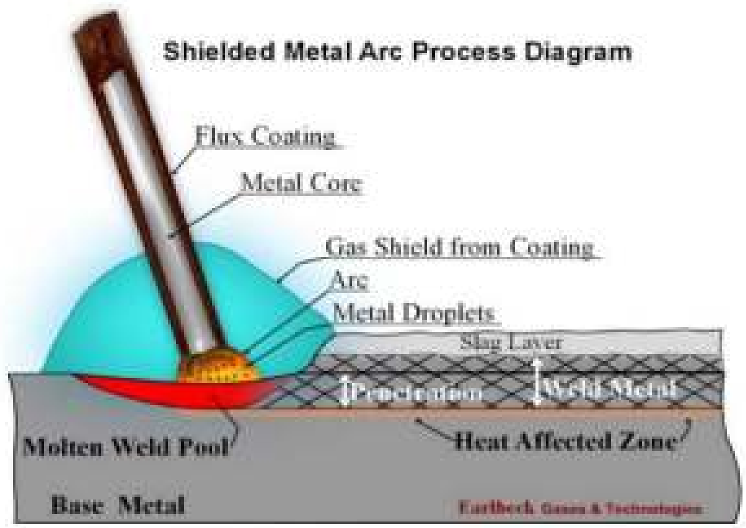



Figure 1.1. Manual metal arc welding diagram

### 1.1.6. Polarity

There are two common types of current flow:

1. Alternating current (AC)
2. Direct current.(DC)

**1. Alternating current (AC)**

Alternating current (AC): Is an electrical current that has alternating negative and positive values.

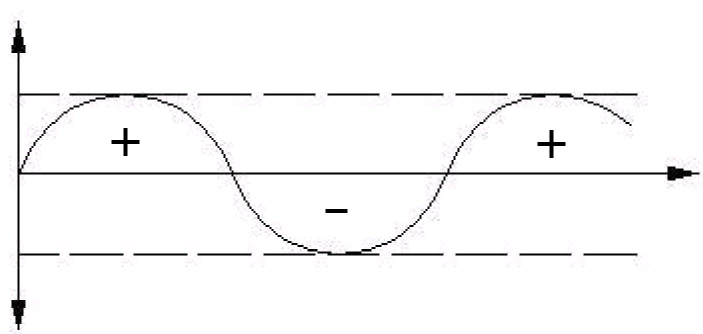


Figure 1.2. Alternating current

Then, here the electric current will change constantly its polarity. However this problem is good to avoid the arc blow when large intensity of current and electrode diameter are in use.

Advantages:

- It is less susceptible to arc blow than direct current. (You will be able to weld with higher current and large diameter electrodes.

Disadvantages:

- Atmosphere gases (oxygen, nitrogen) penetrate to the weld puddle (Although that quantity is just small). This can produce a weld bead with a slightly less strength and ductility than that obtained with direct-current.
- You cannot change the polarity. (Then DC will be better when you are welding in out of positions, for example: overhead position) In this case you should use reverse polarity.

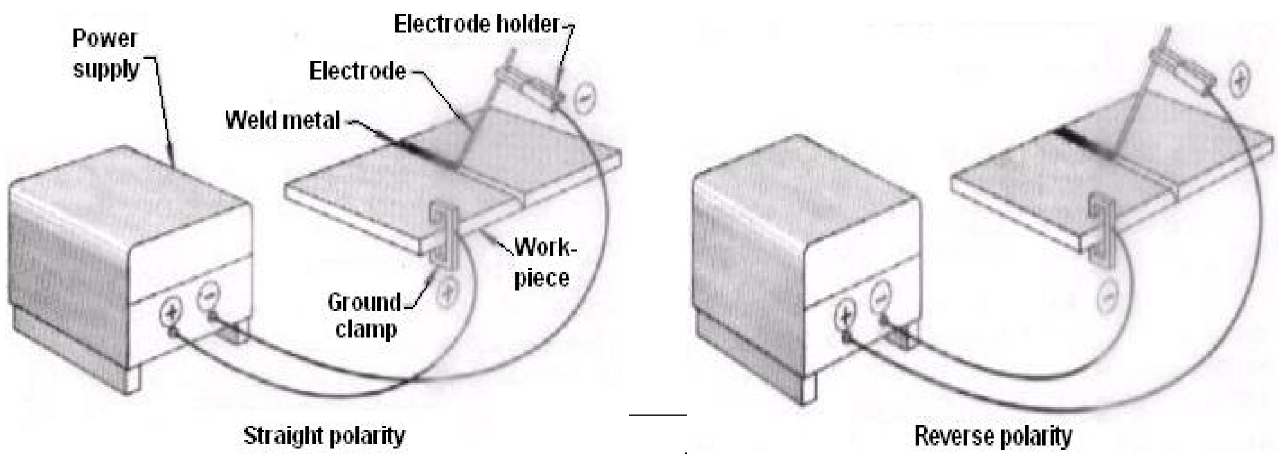
**2. Direct current. (DC)**

Like you know direct current is an electrical current that flows in one direction only. When using dc welding machines, you can weld with either:

- Straight polarity. (Negative electrode)
- Reverse polarity. (Positive electrode)

In straight polarity, the electrode is negative and the work piece positive; the electrons flow from the electrode to the work piece.

In reverse polarity, the electrode is positive and the work-piece negative; the electrons flow from the work piece to the electrode.



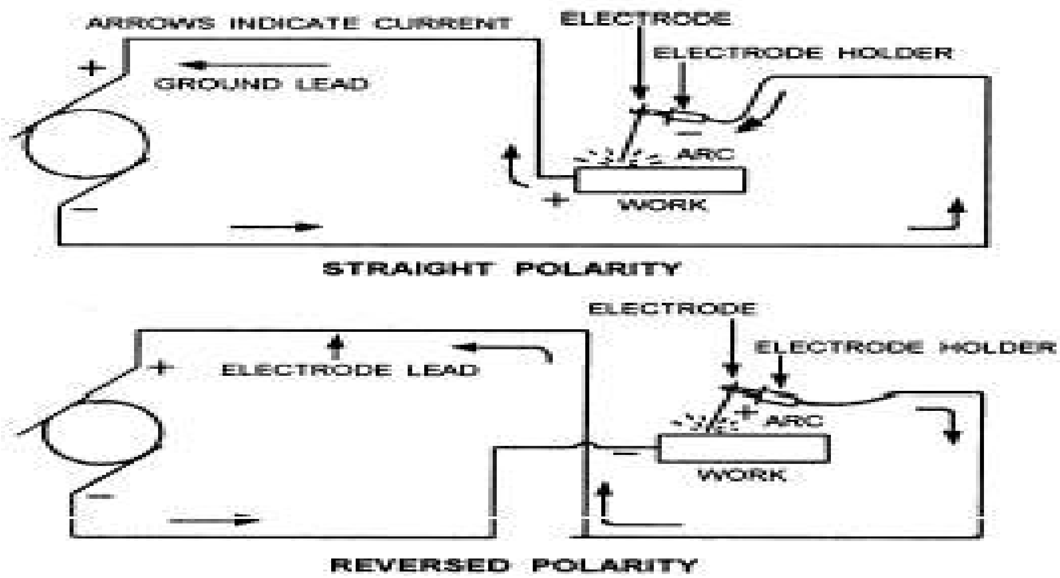



Figure 1.2. Straight and Reverse Polarity of arc welding process

Polarity affects the amount of heat going into the base metal. By changing polarity, you can direct the amount of heat to where it is needed. In some welding situations, it is desirable to have more heat on the work piece because of its size and the need for more heat to melt the base metal than the electrode: In general:

Straight polarity:

- All mild steel, bare, or lightly coated electrodes.
- With these types of electrodes, the majority of heat is developed at the positive side of the current, the work piece.
- When making large heavy deposits

Reverse polarity:

- In the welding of nonferrous metals, such as aluminum, bronze, Monel, and nickel.
- Less heat is concentrated at the work piece. This allows the filler metal to cool faster, giving it greater holding power.
- Reverse polarity is also used with some types of electrodes for making vertical and overhead welds.

- The heat is concentrated on the electrode.(For this reason it is good for welding in overhead position).

**Advantages of direct current.**

- The arc stream is always protected from Atmosphere gases (oxygen, nitrogen) and this cannot penetrate to the weld puddle. It can produce a weld bead with a slightly greater ductility than that obtained with AC.
- You can change the polarity. (Then DC will be better when you are welding in out of positions, for example: overhead position) In this case you should use reverse polarity.
- You can obtain more or less heat in the work piece or in the electrode by changing the polarity.

**Disadvantages:**

- It is more susceptible to arc blow than AC.

In general, straight polarity is used for all mild steel, bare, or lightly coated electrodes. With these types of electrodes, the majority of heat is developed at the positive side of the current, the work piece. However, when heavy-coated electrodes are used, the gases given off in the arc may alter the heat conditions so the opposite is true and the greatest heat is produced on the negative side. Electrode coatings affect the heat conditions differently. One type of heavy coating may provide the most desirable heat balance with straight polarity, while another type of coating on the same electrode may provide a more desirable heat balance with reverse polarity.

Reverse polarity is used in the welding of nonferrous metals, such as aluminum, bronze, Monel, and nickel. Reverse polarity is also used with some types of electrodes for making vertical and overhead welds.

### 1.1.7. Welding symbol and requirements

Special symbols are used on a drawing to specify where welds are to be located, the type of joint

Special symbols are used on a drawing to specify where welds are to be located, the type of joint
to be used, as well as the size and amount of weld metal to be deposited in the joint.

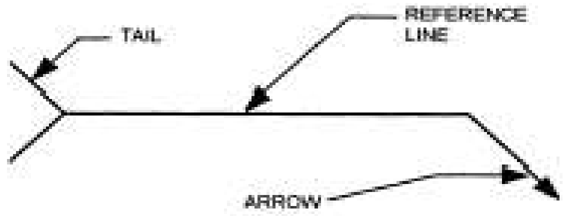


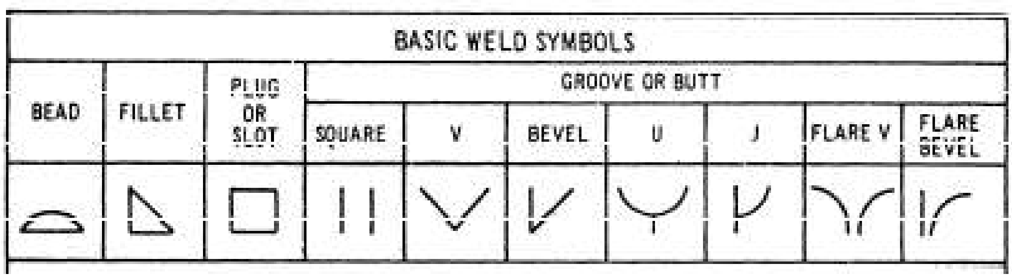

Figure 1.3. Standard welding symbols

A standard welding symbol on the above figure 1.3 consists of: A reference line, an arrow, and a tail.

- The reference line is used to apply weld symbols, dimensions, and other data to the weld.
- The arrow simply connects the reference line to the joint or area to be welded.
- The tail of the welding symbol is used only when necessary to include a specification, process, or other reference information.

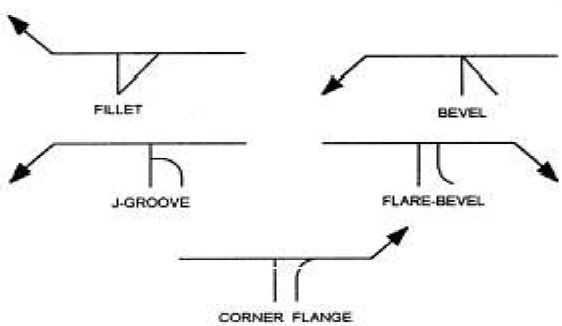
**Weld Symbols**

The term ***weld symbol***refers to the symbol for a specific type of weld. (Fillet, groove, surfacing, plug, and slot are all types of welds. The weld symbol is only part of the information required in the welding symbol.



| BASIC WELD SYMBOLS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| BEAD | FILLET | PLUG OR SLOT | GROOVE OR BUTT | | | | | | | |
| | | | SQUARE | V | BEVEL | U | J | FLARE V | FLARE BEVEL | |

Figure 1.4. Basic welding system




(How a weld symbol is applied to the reference line.)

Figure 1.5. Weld symbolapplied to reference line

What is the significance of the positions of the weld symbols position on the reference line? If the weld symbol is on the lower side of the reference line that is termed the ***arrow side.*** Ifthe weld symbol is on the upper side of the reference line that is termed the ***other side***. When weld symbols are placed on both sides of the reference line, welds must be made on both sides of the joint.

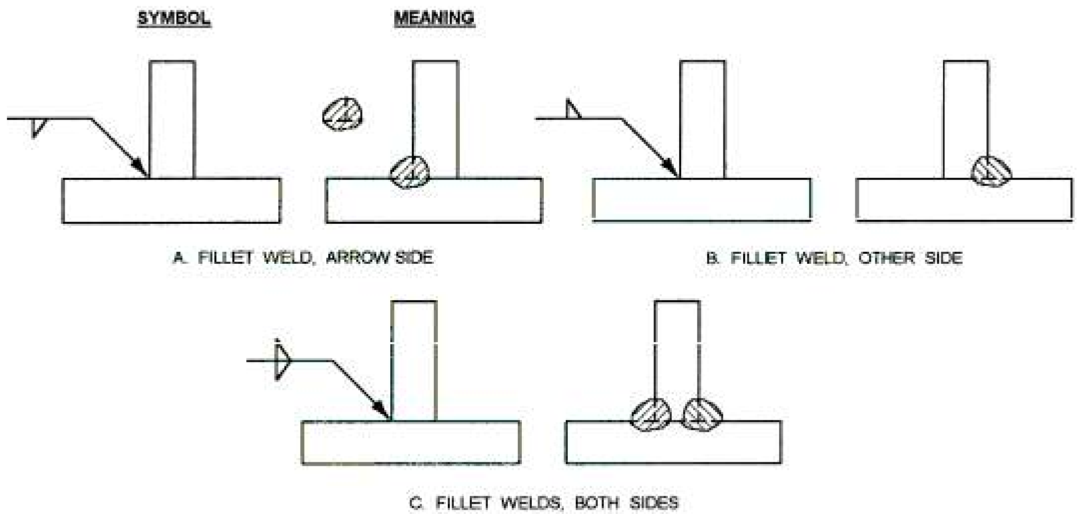
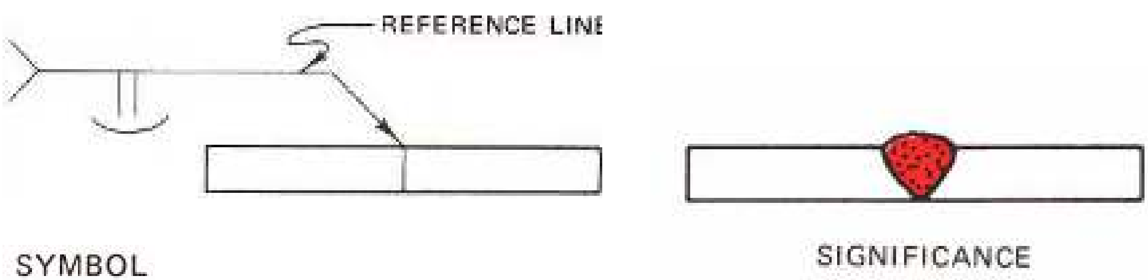
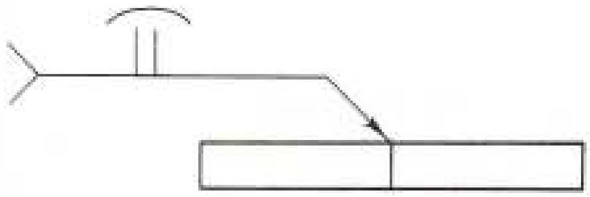



Figure 1.6. Specifying weld location

Dimensions:Left side of a weld symbol you place the size and on the right side you place the length of weld.


Figure 1.7. Dimension

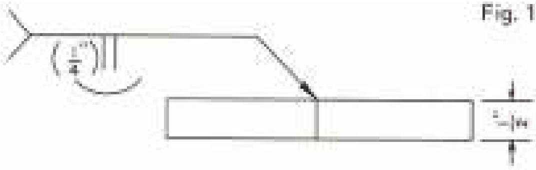




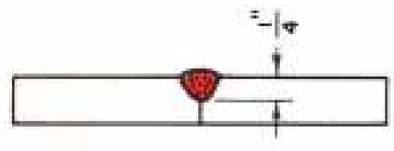
SYMBOL

SIGNIFICANCE

Fig. 13



SYMBOL



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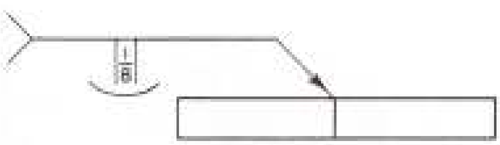
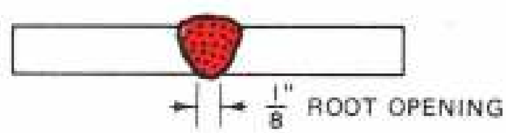


SYMBOL

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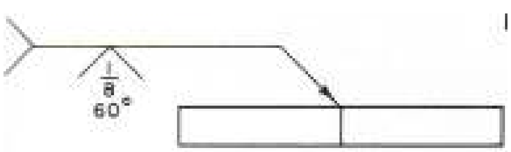


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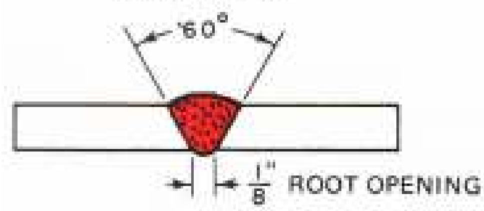


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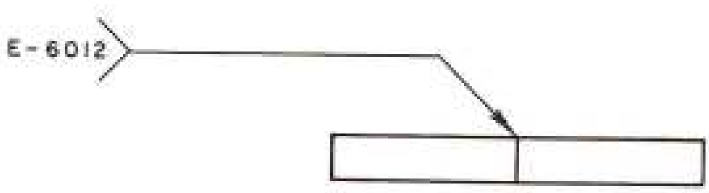


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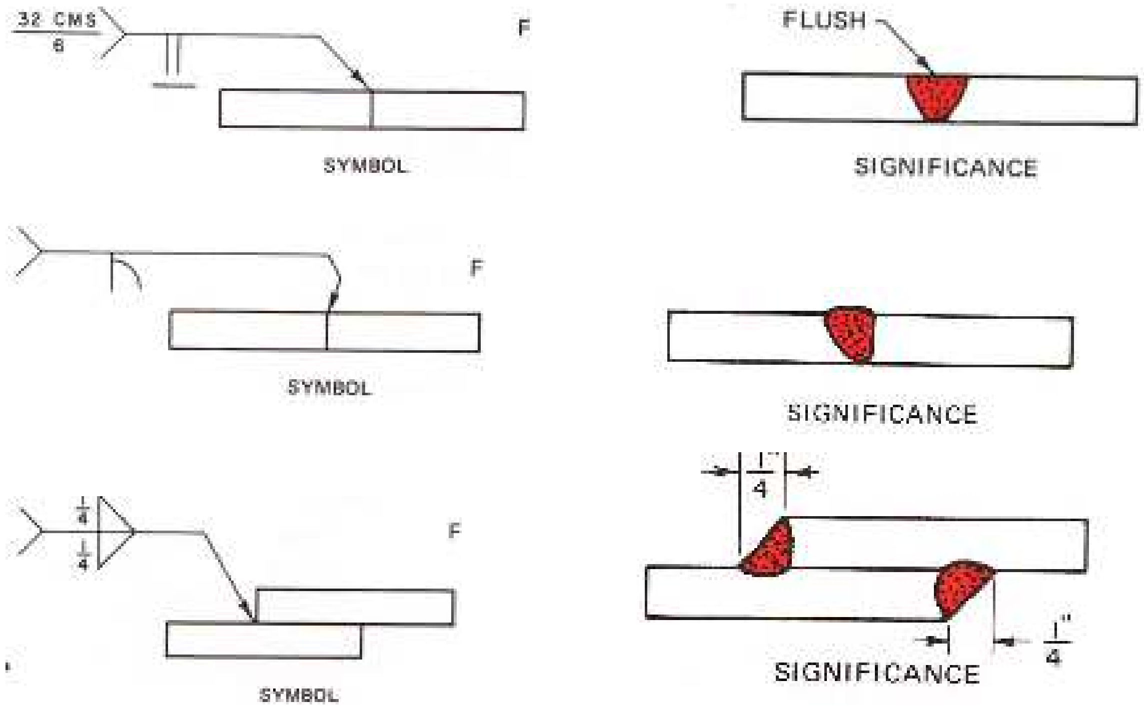



Figure 1.8.Preparing materials to the required weldspecification.

Some of the other welding requirements are: select proper welding machine, Select welding current, and Identify welding location within the recommended safety precautions. Under welding location, the term by itself means that the area of welding operation is performed and typical welding shop would incorporate in the following feature:

- Heavy duty load bearing flours, preferably of concrete.
- Fire resistance structure
- Well ventilated building and have provision for localized exhaust ventilation
- Means of transportation heavy materials
- Heavy duty power supply
- All personal safety equipment should be exist
- Welding area should be free of flammable structure
- Welding area should be convenient for performing welding operation.

## 1.2. Welding materials and equipment or tools

### 1.2.1. Welding materials by MMAW/SMAW

SMAW dominates other welding processes in the maintenance and repair industry in particular. Althoughflux-cored arc welding is growing in popularity, SMAW continues to be used extensively in theconstruction of steel structures and in industrial fabrication. The process is used primarily toweld iron and steels, including stainless steel, but most alloys can be welded with this method. When the steel composition is easily identifiable, rutile electrodes can be used as they are easier to strike and to weld and give a good-looking seam.

In practice, welding of medium, high carbon steels (>0.25%) can cause the formation of structural defects; application of the electrode procedure is recommended mainly for welding medium to thick joins using basic electrodes: in these cases a high quality weld is obtained with good breakage resistance.

Steel pipe welding is carried out using cellulose electrodes, where high penetration and good electrode workability are required. Beveling is always recommended, with a bevel angle that is sufficient to allow almost complete electrode insertion into the welding gap. For special materials such as stainless steel, aluminum and its alloys, cast iron, specific electrodes for the particular material are used.

Stainless steels are welded with direct current (DC) with reverse polarity; special electrodes are used and are differentiated by the metallurgical composition of the material to be welded (presence of chrome (Cr) and of Nickel (Ni) in variable proportions).

Aluminum and light alloys are welded with direct current (DC) with reverse polarity. The machine should be equipped with rather a high strike dynamic to guarantee electrode strike. Also in this case special electrodes are used and are differentiated by the metallurgical composition of the material to be welded (presence of Magnesium (Mg) and of Silicon (Si) in variable proportions).

Cast iron is welded with direct current (DC) with reverse polarity; the majority of cast iron structures and machine members are obtained by casting, so that welding is used to correct possible casting defects or for repairs. Special electrodes are used and the base material should be heated sufficiently before use.

### 1.2.2. Arc welding tools

Arc welding tools are used to perform a welding operation: some of them are:

1. Chipping hammer: Has two striking ends, a pointed end and a flat end that runs parallel to the handle as shown fig.

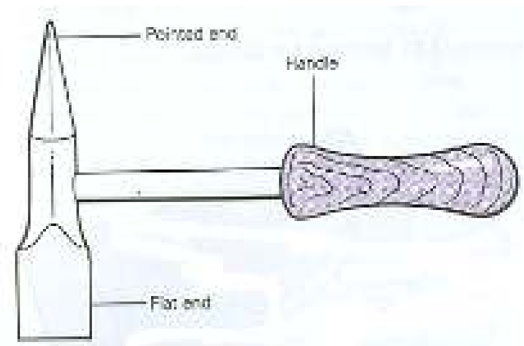



Figure 1.9.Chipping hammer

2. Wire brushes: are used to clean the work piece and for further cleaning of the weld bead. This helps to expose any blowholes that might need to be refilled. The bristles are made from steel or stainless steel. See the following fig.

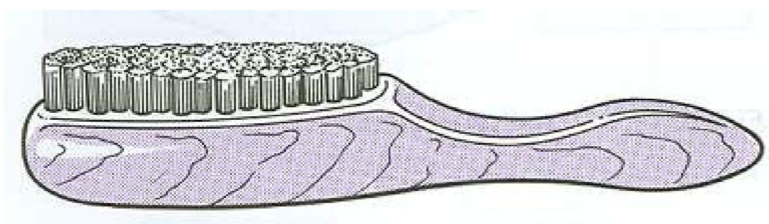


Figure 1.10.Wire brush

3. Tongs: are used for holding and picking up hot metals in welding. It is made of wrought iron or mild steel, in lengths from 400 mm to 650 mm in steps increasing by 50 mm, and is sold by weight. Its parts are: Handles or reins, Pin and Jaws.

There are varieties of Tongs designed to grip different types of work pieces with various shapes. The common types are shown in figure 1.11-1.18.

- Close mouth:you use this type for holding very light rectangular work pieces.

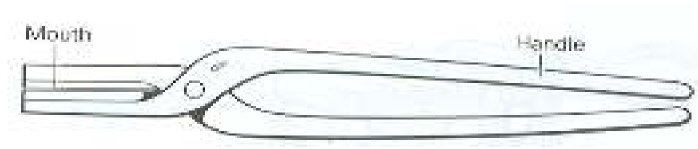



Figure 1.11.Close mouth tong

- Open mouth:this has a flat open mouth that, when closed still has the jaws opened. You Use it for holding thick regular pieces.

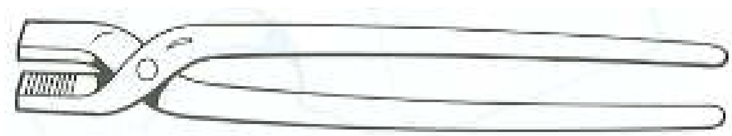


Figure 1.12.Open mouth tong

- *Hollow bit:*the mouth forms acicular hole when closed, which makes it useful for holding round or square bars length wise .it is also referred to as a *round bit.*

Figure 1.13.Hollow bit tong

- Pick – up or dandy:you use this for picking up and holding hot metals, but not for holding work during forging.

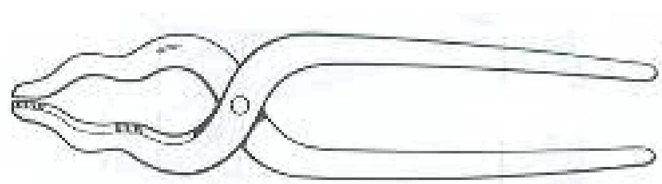


Figure 1.14.Pick – up or dandy ton

- Vee bit:this has a vee mouth for holding square bars lengthwise.

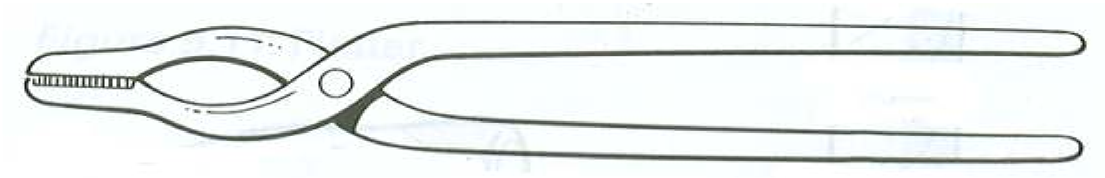


Figure 1.15.Vee bit tong

- Box or square mouth:you uses this for holding heavy square or rectangular pieces.

Figure 1.16.Box or square mouth tong

- Scroll tongs:you uses these for making scrolls.

Figure 1.17.Scroll tong

4. Universal tongs:  these have three holes and a grove along the jaws, for general use.

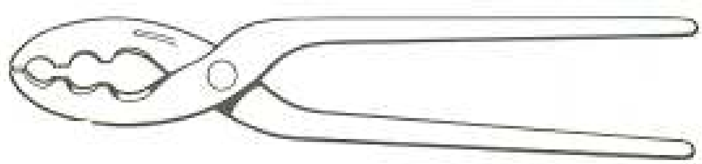


Figure 1.18.Universal tongs

### 1.2.3. Arc welding equipment

A wide variety of welding equipment is available, and there are many differences between the makes and models of the equipment produced by the manufacturers. However, all types of arc-welding equipment are similar in their basic function of producing the high-amperage, low-voltage electric power required for the welding arc. In this discussion, we are primarily concerned with the typical items of arc-welding equipment, rather than the specific types. For specific information about the equipment your battalion or duty station has available, consult the manufacturer's instruction manual.

The basic parts of a typical shielded metal-arc welding outfit include a welding machine, cables, electrode holder (stinger), and electrodes. The steelworkers also requires a number of accessories that include a combination chipping hammer and wire brush, welding table (for shop work), C-clamps, and protective apparel. Before we discuss the different types of welding machines, you must first have a basic knowledge of the electrical terms used with welding.

Arc welding equipment is the basic equipment used for the purpose of joining two or more work pieces together. This equipment is:

- Welding machine
- Welding cables
- Electrode holders
- Ground clamps

1. **Arc welding machines**

The power source used in arc welding is called a welding machine or a welder. Arc welding machines are equipment that provides current to produce an electric arc when the electrode is struck on the work pieces. The three basic types of arc welding machines are; -

1. The generator (engine driven) welding machines
2. The transformer (AC) welding machines
3. The rectifier (motor generator) welding machines

Among the three machines mentioned above, the common one that is mostly applicable in the workshops is the transformer (AC) welding machines; and is explained below

The transformer (ac) welding machines:The transformer welding machines operate on an electrical supply. The powers supply may be 220 volts or more, which is too high for welding. The transformer therefore reduces the voltage and provides the appropriate current for welding.

Transformer welding machines are strongly built light and run quietly. They cannot be used at sites where there is no electricity.

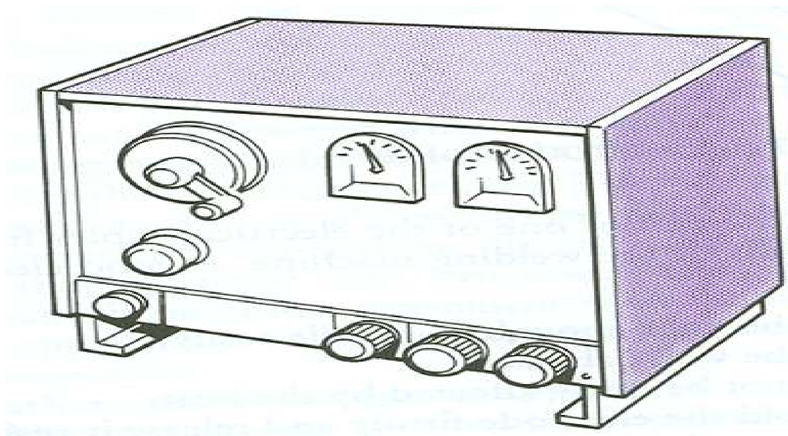


Figure 1.19.Arc welding machine

**2. Arc welding cables**

Two cables of adequate sizes and well-built are necessary to carry the current from the welder to the work and back to the welder. The ground cable is attached to the work pieces or table and the other cable is attached to the electrode holder.

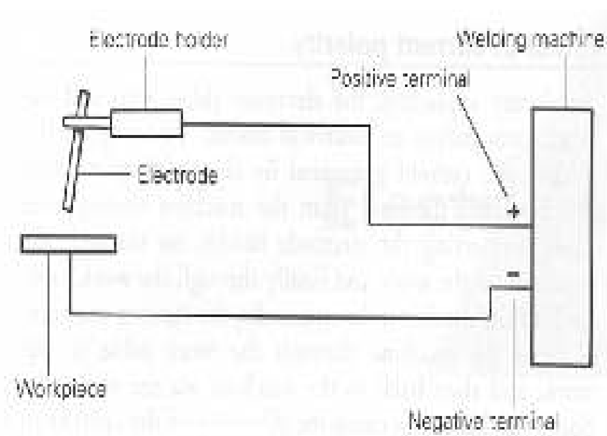



Figure 1.20.Arcwelding cable

**3.Electrode holder**

The electrode holder is the part of the arc welding equipment held by the welder. It is attached to the electrode cable on the welding machine.An electrode holder, commonly called a stinger, is a clamping device for holding the electrode securely in any position. The welding cable attaches to the holder through the hollow insulated handle. The design of the electrode holder permits quick and easy electrode exchange. Two general types of electrode holders are in use: insulated and non-insulated. The non-insulated holders are not recommended because they are subject to Accidental short circuiting if bumped against the work-piece during welding. For safety reasons, try to ensure the use of only insulated stingers on the jobsite.

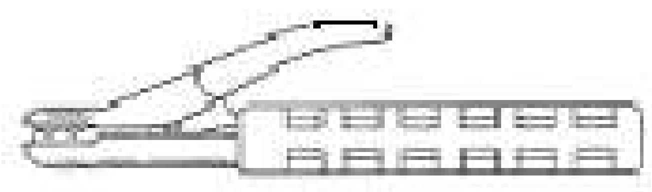


Figure 1.21.Electrode holder

**4.Ground clamp**

The use of a good ground clamp is essential to producing quality welds. Without proper grounding, the circuit voltage fails to produce enough heat for proper welding, and there is the possibility of damage to the welding machine and cables. Three basic methods are used to ground a welding machine. The ground cable from the machine to the work is generally connected to a spring-loaded clamp, which can be easily attached to the work. In order to do a good job of welding, the ground must be solidly connected to the work.

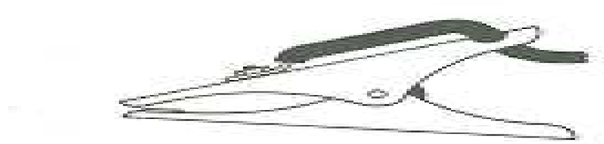
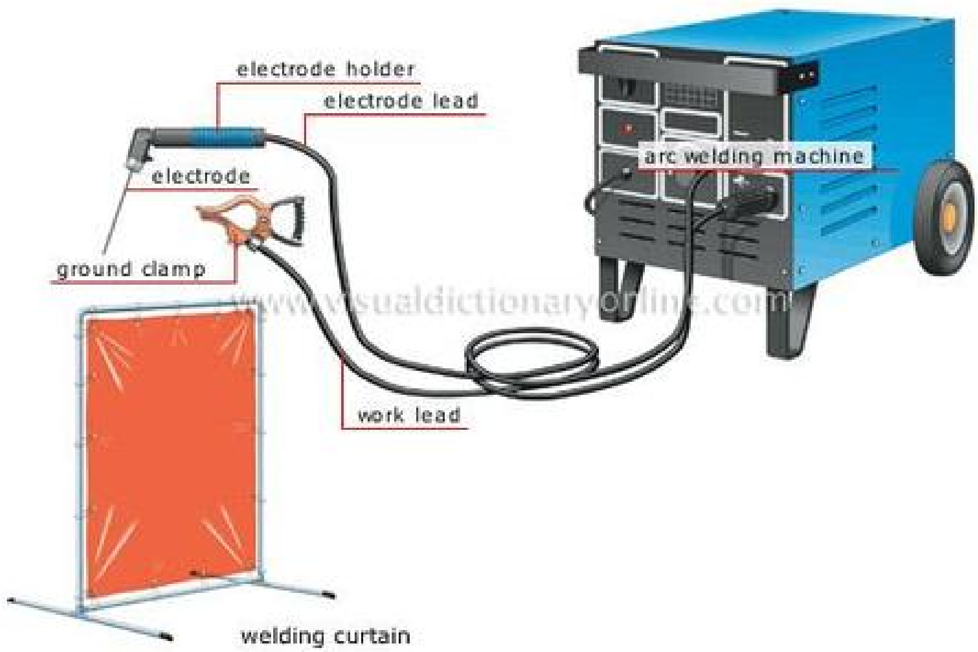


Figure 1.22.Ground clamp

**5. Cleaning Equipment**

Strong welds require good preparation and procedure. The surface area of the work piece must be free of all foreign material, such as rust, paint, and oil. A steel brush is an excellent cleaning tool and is an essential part of the welder's equipment. After initial cleaning and a weld bead have been deposited, the slag cover must be removed before additional beads are added. The chip-ping hammer was specifically designed for this task. The chipping operation is then followed by more brushing, and this cycle is repeated until the slag has been removed. When the slag is not removed, the result is porosity in the weld that weakens the weld joint.



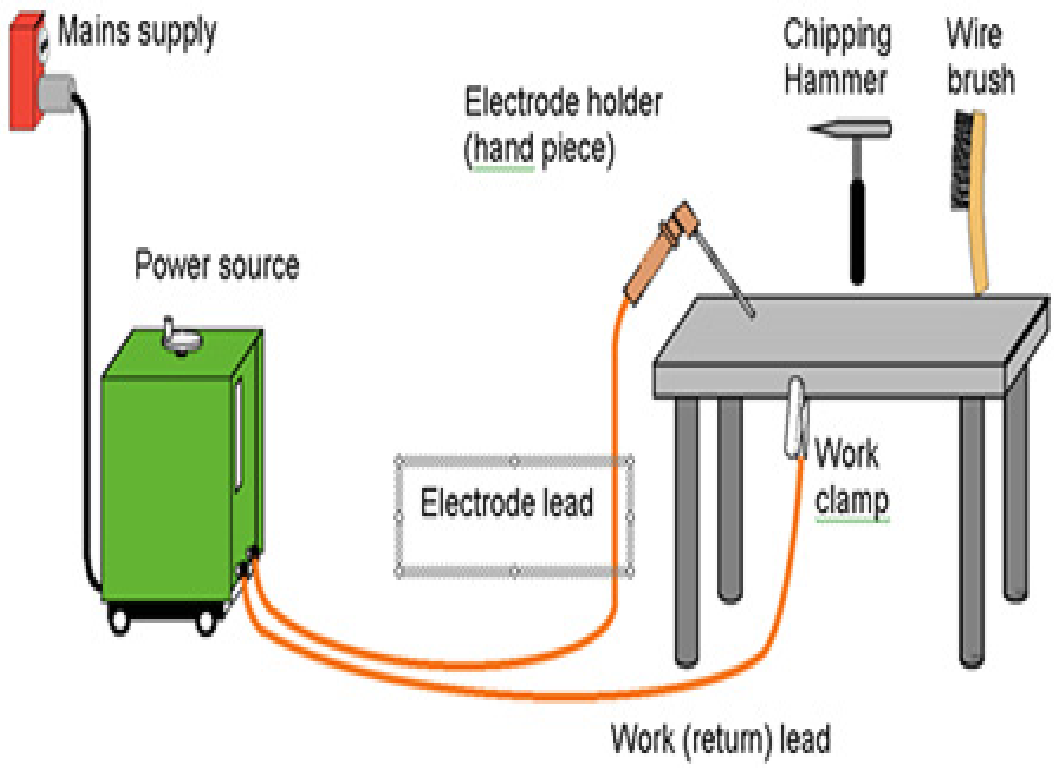



Figure 1.23. The overall view of manual arc welding equipment and tools

## Self-check-One

**Instruction one: Choose the correct answer.**

1. ----------------------is used for holding the electrode manually and conducting current to it.

A.Welding cables B. Electrode holder C. Weldingmachine D. Welding electrode.

2. Which one of the following is not the type of welding equipment?

A. Welding cable B. ground clamp C. anvil D. welding machine

3. ____________________ are used for holding and picking up hot metals in welding.

4. Which one of the following is a not arc welding tool?

A. Anvil B. Close mouth tong C. Wire brush D. Chipping hammer

5. Which one of the follow is not part of the tong?

A. Handles or reins B. Pin C. blade D. Jaws

6. What are the distance b/n electrode and the work piece in SMAW process?

A.Arc length B.Welding speed C.Welding current D.Welding cable

7. It is Use to protect your eyes from ultraviolet rays

A. Apron B. helmet C. goggle D. all

8. In welding electrode symbol E-7018 ; 70-stand for

A. Tensile strength B. Electrode C. Welding position D. All of the above

**Instruction two: Matching**

A B

1.It provides current to produce an electric arc A. Electrode holder

2. Personal protective equipmentB. Tongs

3. Used for holding and picking up hot metals in welding C. Welding machine

4. A rod that is used in arc welding to carry a current through a work piece D. Apron

5.Manually hold the electrodeE. Electrode

## Operation sheet: 1

**Operation title:** Identification of welding tools and equipment

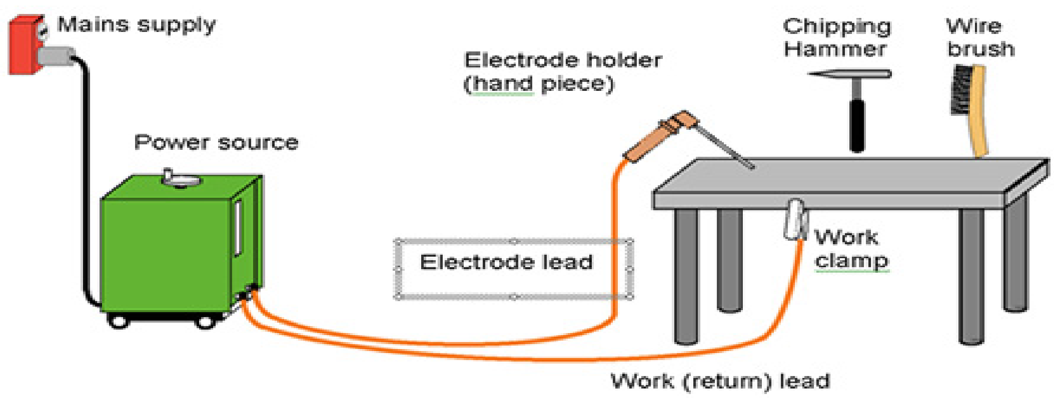
**Purpose:** the main purpose of the operation is to now the correct welding equipment and tools

**Condition or situation of the operation:** to identify the proper tools and equipment will ready or available the necessary material.

**Equipment tools and materials:** Standard AC or DC welding machine, welding cables, welding clamp, electrode holder, Chipping hammer and Wire brush.

**Procedure:**

1. Understand the welding requirements
2. Know the main use of the tools and equipment
3. Identify the fundamental working process of the operation
4. Check the functionality of the operation




**Precaution:** The welder must have properly now the each welding equipment and tools of the operation.

**Quality criteria:** fully understand the working conditions of the equipment and tools.

## Lap Test: Practical Demonstration

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4 hour.

Task 1. Identifying the correct welding requirements

Task 2. Selecting the welding material

Task 3.Identify appropriate welding equipment

## Unit Two: Welding Practicesand principles

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Set up of welding current
- Electrode Selection
- Materials preparationand Cleaning
- Welding materials
- Clean welding seams or joints
- Measurement of OHS
- Application of personal protective equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify the welding parameters
- Select the proper welding electrode
- Perform welding materials preparation and cleaning
- Identify the welding material
- Perform clean in welding seams or joints
- Applying OHS measures
- Apply the correct personal protective equipment

## 2.1. Setup of welding current

The welding quality of the shielded metal arc welding is determined by the welding parameters / characteristics including the welding slot forms, electrode diameter, welding current, welding speed, arc length, electrode advance angle, electrode oscillation angle and movement, welding direction and position, etc. In an effort to obtain high quality welds in shielded metal arc welding method, selection of ideal parameters should be performed according to engineering facts. To properly selecting the welding current we considered the following mentioned points:

- Welding current is one factor to obtain a proper bead.
- Factors to be secure a weld that has a proper penetration:-
- Correct arc length
- Correct types of electrode
- Correct current setting
- Correct speed of travel
- Correct electrode angles
- Select proper polarity for the given welding

### 2.1.1. Material type

Welding application will be realized for three different materials; namely plain carbon steel, alloy steel and stainless steel. Aluminum is not recommended for shielded metal arc welding method; therefore it is excluded in this technique.

### 2.1.2. Electrode diameter

The electrodes used in shielded metal arc welding are divided in two main groups as joining and filler welding ones according to the purpose of the welding. The coated electrodes are also classified by the tensile strength of the deposited weld metal, the welding position in which they may use, the preferred type of current and polarity, and the type of coating. The metal wire used in the process is usually from 1.5 to 6.5 mm in diameter and 20 and 45 cm in length. The electrode material in welding is desired to be high strength, ductile and tough. The molten electrodes provide both forming of arc and filling the welding area. According to EN ISO 2560:2005 standard, the electrodes are determined in the welding for plain carbon and low alloy steels. For selection of electrode; material type, welding position, welding current, welding slot form and work piece thickness above all are taken into consideration. The electrode diameter changes according to the material thickness and welding slot form. The most used electrodes in shielded metal arc welding applications are 2.50, 3.25 and 4.00 mm core diameter ones .The values of electrode core diameters are determined in Table 2.1, depending on work piece thickness.Electrode Size are commonly made in lengths 250 mm, 300 mm, 350 mm, 450 mm, and the diameters are 1.6 mm, 2 mm, 2.5 mm, 3.2 mm, 4 mm, 7 mm, 8 mm and 9 mm.

### 2.1.3.Welding current

During the welding, that is, while arc occurs in welding period, current against working voltage is called as welding current. Welding machine is plugged into the alternative current and poles are determined. The cable tips connecting to electrode pliers and ground one are prepared, then electrode is attached to the pliers and arc occurs when electrode touches to work piece and consequently a permanent current circle continues. Welding current is set by welders prior to welding application. During the welding application, the value of welding current is not changed. However, arc is cut or current can be increased depending on welding application. Welding current is selected as 40 folds of electrode core diameter ($I = d \times 40$). This value can be changed as 10% depending on thickness ofmaterials and position.

Table 2.1.Electrode core diameters suggested by program according to work piece thickness(s)

| Work piece thickness (s) | Electrode core diameter (d) | Unit |
|---|---|---|
| $S \leq 3$ | 2.5 | mm |
| $3 < S \leq 20$ | 3.25 | mm |
| $S > 20$ | 4.00 | mm |

Table 2.2.Welding speeds according to work piece thickness (s), weld current (I) and electrode diameter (d).

| Work piece thickness (S) | Welding speed ($V_k$), mm/s | Welding current (I) |
|---|---|---|
| $S \leq 3$ | 4.50 | d × 40 ampere |
| $S > 3 \leq 8$ | 4.00 | d×40 ampere |
| $S > 8$ | 3.50 | d × 40 ampere |

Table 2.3.The values of ideal advance angle and tolerances depending on welding position.

| Welding position | Advance angle | Tolerance (º) |
|---|---|---|
| Plain weld | 80 | ±5 |
| Cornice (overlap) weld | 80 | ±5 |
| Vertical weld | 105 | ±5 |
| Overhead weld | 80 | ±5 |

### 2.1.4. Welding speed

The movement of arc welding along work piece or the length of weld seam made in unit time is known as welding speed. When the speed is slow during the welding process, stock weld metal increases in the unit length and eventually it causes to enlarge the welding pool. With growing of weld metal and increasing of heat input, the molten metal flows into the front of arc within the welding slot and it affects the regular arc formation. The increment of speed causes to reduction of welding heat given to unit length and consequently the molten quantity of main metal decreases, this negatively affects the wetting of weld seam. The determined welding speeds are given in table 2.2, according to the thickness of work piece (s), welding current (I) and diameter of electrode (d).

### 2.1.5. Arc length

The importance of distance between electrode and work piece is vital for arc occurrence. The mentioning of arc length in various welding applications is required to understand the difference between arc lengths. If arc length is equal to electrode diameter, this is called as normal arc length. Long arc is obtained whenever arc length is greater than electrode diameter. The distances less than the electrode diameter are called as short arc length. Experience shows that arc blowing is more effective in case of long arc length comparing to short arc one. For this reason, shortarc length is always recommended for the work. It is also observed from the previous experience that, arc blowing will be less comparing to the uncoated or cored ones in case of welding with coated electrodes. In addition, blowing effect is more in thin coated electrodes comparing to thick ones.

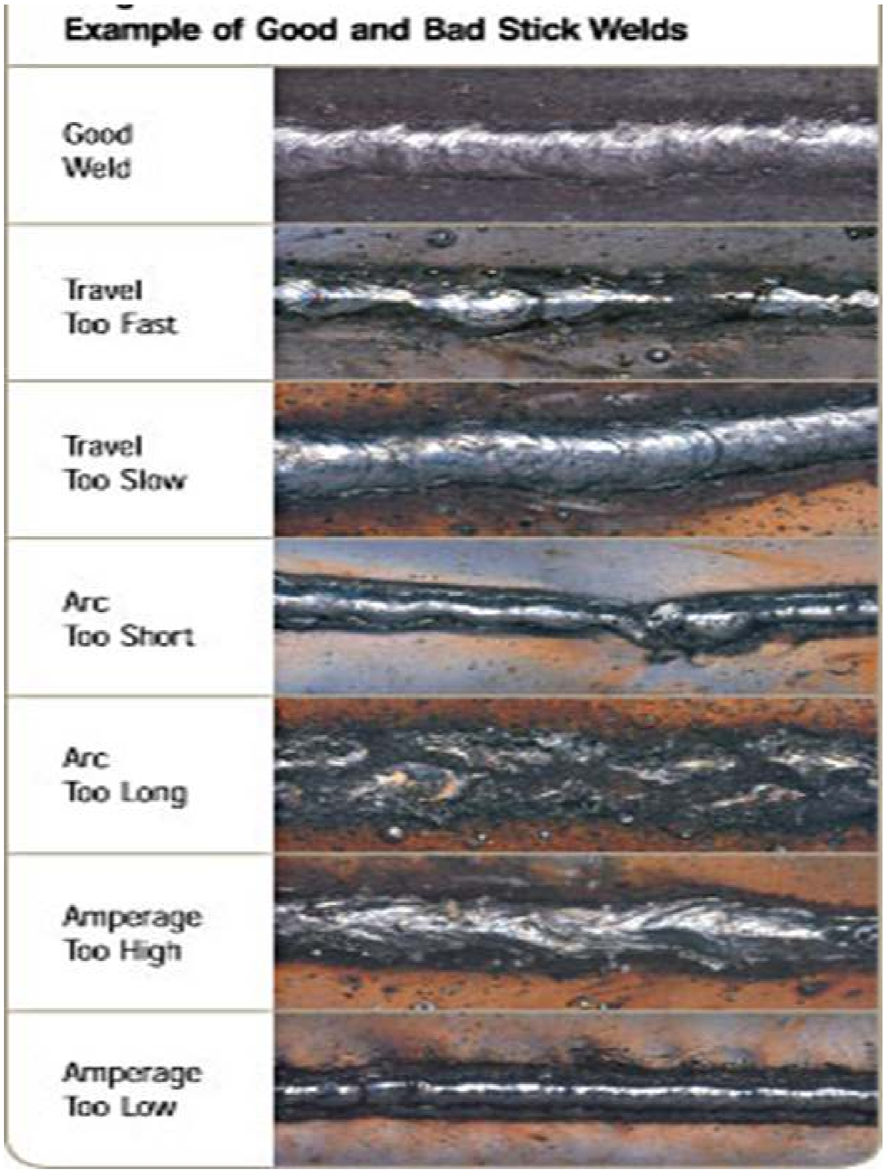



Figure 2.1.Effects of the major weld parameters: speed, current and arc length

## 2.2. Types of electrode and size

### 2.2.1. Welding electrodes

In electric arc welding, the term electrode refers to the component that conducts the current from the electrode holder to the metal being welded. Electrodes are classified in to two major groups: consumable and non-consumable.

- Consumable electrodes not only provide a path for the current but they also supply filler metal to the joint. An example is the electrode used in shielded metal arc welding.
- Non-consumable electrodes are only used as a conductor for the electrical current, such as in gas tungsten arc welding. The filler metal for gas tungsten arc welding is a hand fed welding rod.The consumable electrodes are classified in to two types:

**1. Coated electrodes:** Coated electrodes are generally applied in arc welding processes. A metallic core is coated with some suitable material. The material used for core is mild steel, nickel steel, chromium molybdenum steel, etc. One end of the coated core is kept bare for holding.

**2. Bare electrodes:** Bare electrodes produce the welding of poor quality. These are cheaper than coated electrodes. These are generally used in modern welding process like MIG welding.

SMAW electrodes are available to weld carbon and low alloy steels, stainless steels, cast irons, copper, and nickel and their alloys, and for some aluminum applications. Low melting metals, such as lead, tin, and zinc, and their alloys, are not welded with SMAW because the intense heat of the arc is too high for them. SMAW is not suitable for reactive metals such as titanium, zirconium, tantalum, and columbium because the shielding provided is inadequate to prevent oxygen contamination of the weld. The function of Coatings on an electrode serves as the following functions:

1. To prevent oxidation.

2. Forms slags with metal impurities.

3. It stabilizes the arc.

4. Increases deposition of molten metal.

5. Controls depth of penetration.

6. Controls the cooling rate.

7. Adds alloy elements to the joint.

## 2.2.2. Selection factors for electrodes

A number of factors come into play when selecting a shielded metal arc welding (SMAW) electrode for carbon steels. SMAW electrodes are consumables that serve multiple purposes, providing both filler metal and flux. The filler metal is consumed by the weld pool while the flux functions to protect it from atmospheric gases by generating a shielding gas or protective slag when superheated during welding. The factors include the following:

### A. Base metal

The base metal largely dictates the type of filler metal that can be used. The weld pool is composed of the base metals and the filler metal supplied by the electrode. When the welding steel tensile strength of the filler metal should generally match that of the base metal as closely as possible. When joining dissimilar steels, the tensile strength of the electrode should generally match that of the weaker base metal. This helps minimize or prevent any dissolution or discontinuities that could weaken the joint.

Electrode hydrogen content and alloying elements present in the base metal also come into play when selecting an electrode. Low-hydrogen steel electrodes are preferred when joining high-carbon, low-alloy, or high-strength steels, as they produce a high-strength ductile joint with medium penetration and high deposition rates. When alloy elements are present in the base metal or when dealing with specific codes, such as those defined by the American Petroleum Institute (API) or the American Society of Mechanical Engineers (ASME), electrodes with specific alloying elements and concentrations may be necessary.

Base metal thickness is yet another factor to consider. Thin metals require an electrode that will produce a soft arc while thicker metals require deeper penetration, which is a function of welding current, welding polarity and flux. Larger diameter electrodes are suitable for handling larger currents, although a greater current will be required to achieve the same penetration achieved with a thinner electrode.

### B. Weld position

A flat weld is the preferred welding position. This helps ensure proper shielding and minimizes any irregularities within the weld pool. In field operations where SMAW operations are most prevalent, the operator typically cannot manipulate the work piece. It is therefore important to select an electrode that is designed for the particular welding position, whether flat, horizontal, vertical or least preferential and overhead welds.

**C. Flux, current and polarity**

The power source and polarity used to generate an arc dictate the type of flux used on a SMAW electrode. Most operators perform SMAW using direct current electrode positive (DC+). A DC+ power source will work with most types of fluxes. It offers the best penetration and provides a more consistent output when compared to alternating current (AC) power sources. Direct current electrode negative (DC-) works well when dealing with thinner profiles, as it provides shallow penetration and a quicker burn rate.

AC power sources require a fluxed electrode that will help maintain the arc while the current and polarity fluctuate. AC power sources do, however, help overcome arc blown problems typically experienced when welding with thicker electrodes or in cases where the arc has a tendency to wander outside of the welded joint.

### 2.2.3. Electrodedesignations

Electrodes are often referred to by a manufacturer's trade name. The American Welding Society (AWS) and the American Society foresting and Materials (ASTM) have set up certain requirements for electrodes to assure some degree of uniformity in manufacturing electrodes.

All major manufacturers of welding electrodes use the American Welding Society (AWS) code of specifications. Each company makes basically the same quality which is established by the AWS.

Electrodes are classified according to type of coating, composition of the weld metal and operating characteristics. The numbering system is started with "E" for electrode and then followed by a four digit number each number in the four number sequences has a specific meaning. Electrodes are classified into 5 main groups depending on their composition.

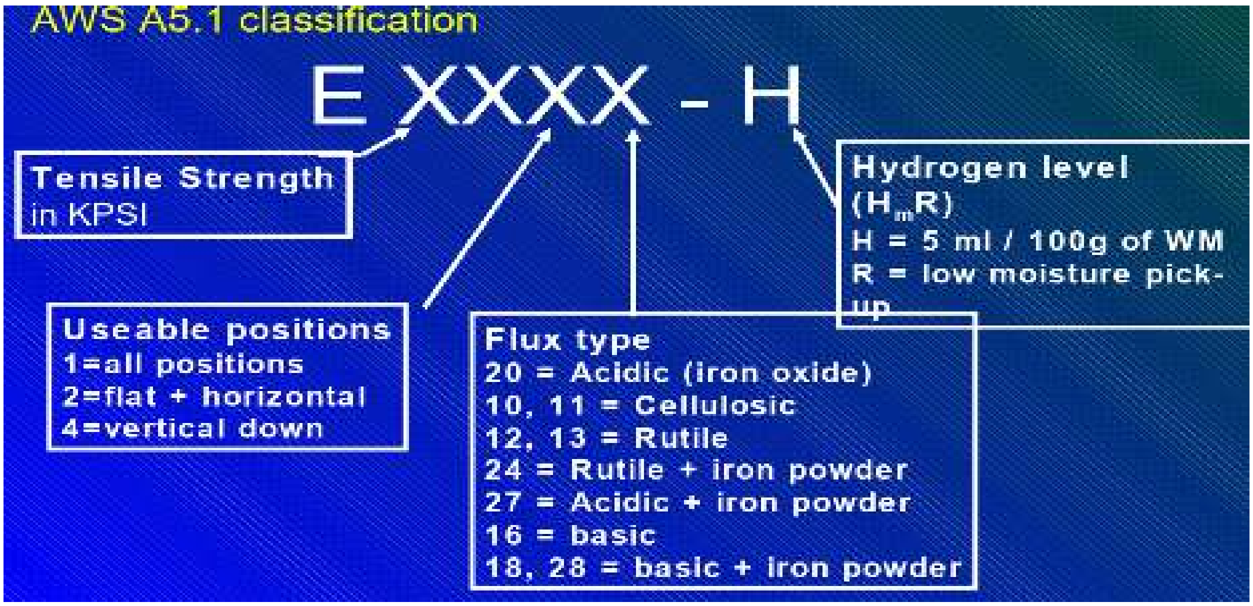
i. **Mild steel: Majority of welding**
ii. **High-carbon steel**
iii. **Special-alloy steel**

iv. **Cast iron**

v. **Non-ferrous**

Example: Aluminum, Copper, & Brass

Thus different manufacturer's electrodes that are within the classification established by the AWS and ASTM should have the same welding characteristics. (See figure 2.2.).



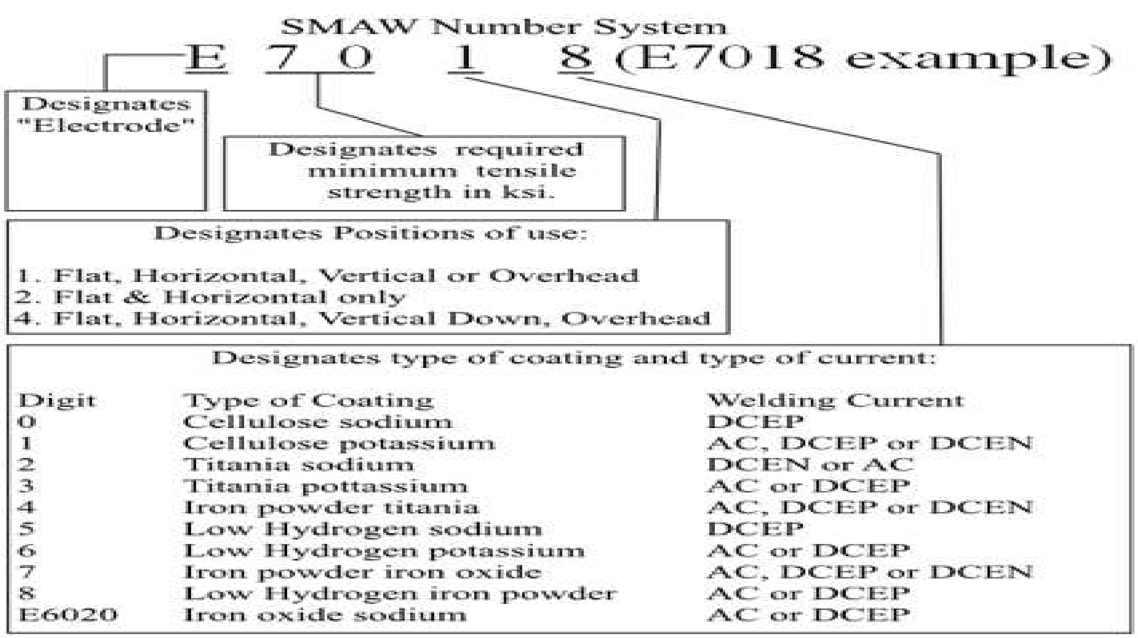




Figure 2.2. Explanation of AWS classification numbers

In this classification, each type of electrode is assigned a specific symbol, such as E-6010, E-7010, and E-8010. The prefix E identifies the electrode for electric-arc welding. The first two digits in the symbol designate the minimum allowable tensile strength in characteristics of the electrode, thousands of pounds per square inch. For example, the 60-series electrodes have a minimum tensile strength of 60000 psi. The third digit of the symbol indicates the joint position for which the electrode is designed. Two numbers are used for this purpose:

- Number 1 designates an electrode that can be used for welding in any position.
- Number 2 represents an electrode restricted for welding in the horizontal and flat positions only.

The fourth digit of the symbol represents special characteristics of the electrode (8 numbers are used for this purpose), such as weld quality, type of current, and amount of penetration (figure 2.2).

### 2.2.4. Electrode Selection

Electrode selection these are:

1. Electrode type.
2. Electrode diameter.

The selection of Electrode type of electrode and size is based on a acknowledge of:

1. The position in which the work is to be welded.
2. The type and thickness of the metal being used.
   Te preparation of the work with regard to fittup.( a narrow vee, a small-diameter electrode is always used to run the first weld or root pass.
3. The type of available welding current.
4. The class of work. (Here is taken in consideration, whether the chief essential is deep penetration, surface quality or obtaining certain mechanical properties.)

Welding electrodes are classified according to whether they are to be used with DC reversed polarity (DCRP), DC straight polarity (DCSP), or alternating current (AC). The electrodes used most commonly for mild steel welding are discussed here.

E-6010 indicates an all-position welding rod (flat, vertical, horizontal, and overhead). It performs best when used with DCRP. Deep penetration can be achieved with this electrode which has a thin coating, and which lends itself particularly well to out-of-position welding.

E-601 1 also indicates an all-position welding rod. It is particularly suited for use with AC, but it can also be used with DCRP and DCSP. Its thin coating makes it a good electrode for out-of-position work.

E-601 2 is another all-position electrode, however, because of its heavier flux coating, it is slightly more difficult to make out-of-position welds with this electrode. It is best suited for use with DCSP or AC.

E-601 3 indicates an electrode which is especially suited for deep-penetration welds in the flat position. Because of its heavier coating it is a more difficult electrode for beginners to use than are the E-601 I electrodes. This electrode can be used with all types of polarity.

E-6020 electrodes have a heavy iron powder flux coating. They are used for flat and horizontal welding only. (Notice that the third digit is 2.) These electrodes can be used with DCRP, DCSP, or AC.

E-6030 electrodes also have a heavy iron powder flux coating. As is indicated by the third digit being 3, they are for flat position welding only. These electrodes may be used with DCRP or AC.

Note: E-6020 and E-6030 electrodes are sometimes called drag rods. This is because the welder can run a bead without removing the rod from the parent metal once the arc is struck.

### 2.2.5. Storage and Condition of Electrodes

All basic electrodes shall be delivered in hermetically sealed containers that do not show evidence of damage. However, if such containers show evidence of damage, the electrodes shall be reconditioned in accordance with the requirements of the standard. Immediately after being removed from hermetically sealed containers or from reconditioning ovens, electrodes shall be stored in ovens held at a temperature of at least 120°C (250°F). Basic electrodes of E49XX classification that are not used within 4 hours after removal from ovens shall be reconditioned in accordance with the requirements of the standard Basic electrodes shall be re-dried no more than once. Electrodes that have been wet shall be discarded. The following precaution must follow for properly store the electrode:

1. Always store them in a dry place at room temperature with 50-percent maximum relative humidity.
2. Moisture causes the coating on electrodes to disintegrate and fall off.
3. Low-hydrogen rods are especially sensitive to moisture.
4. After removing these rods from their original packaging, you should store them in a storage space maintained at a temperature between 250°F (121°C) to 400°F (204°C). (Portable or stationary drying ovens are used to store them).

## 2.3. Materials preparation and Cleaning

### 2.3.1. Material Preparation

The necessary task to perform routine arc welding process was to prepare & clean materials for welding operation. Before you start to weld, ensure that you have all the required equipment and accessories. Listed below are some additional welding rules that should be followed.

- Clear the welding area of all debris (Remain) and clutter.
- Do not use gloves or clothing that contains oil or grease.
- Check that all wiring and cables are installed properly.
- Ensure that the machine is grounded and dry.
- Follow all manufacturers' directions on operating the welding machine.
- Have on hand a protective screen to protect others in the welding area from flash bums.
- Always keep fire-fighting equipment on hand.
- Clean rust, scale, paint, that are to be welded.

The edges or surfaces of parts selected and to be joined by welding shall be prepared by shear, hack saw, power cutter or plasma arc cutting. Where hand cutting is involved the edge will be ground to a smooth surface. All surfaces and edges shall be free from fins, tears, cracks or any other defects which would adversely affect the quality of the weld. Before welding, the work pieces must be thoroughly cleaned of rust, scale and other foreign material. The piece for metal generally welded without beveling the edges; however, thick work pieces should be beveled to ensure adequate penetration and fusion of all parts of the weld. But, in either case, the parts to be welded must be separated slightly to allow better penetration of the weld.

All moisture, grease or other foreign material that would prevent proper welding or produce objectionable fumes, shall be removed. Contact with lead, zinc, or lead or zinc compound shall be avoided due to the potential for hot cracking. All surfaces to be welded shall be wire brushed prior to welding. In multi-pass welds the weld bead shall be wire brushed between passes.

The brushes shall be of stainless steel and be kept exclusively for use on stainless steel and be kept clean and free of contaminants. All other equipment such as grinding discs shall be kept exclusively for use on stainless steels. Back gouging of welds shall produce a groove having a profile and a depth adequate to ensure fusion with the adjacent base metal and penetration into the root of the previously deposited weld metals.

Material preparation for arc welding is depend: Thickness of material being weld, Properties of material, welding Process, you must make sure that the best welding metal surface. Free from oil, grease, pain, rust and other substances. Which affect the welding: Welding should not be performed over excessive oxide scale, Oxide scale: can be removing with a solution, machining or Sanding, Oxide scale causes: dull & desk surface. Material preparation for welding can be done by:

- Machining
- Sanding
- Filing
- Using Solution
- Using wire brushing

Equipment used for preparing materials for welding are: Grinder, Sand paper, File, Wire brush. if excessive Oil & Grease Paint, Rust. It can contaminate the weld and causing welding defect.

### 2.3.2. Preparation of a Joint Edge

To produce good quality welds, the surfaces of the weld joint should be clean of rust, scale, dirt, oil and grease. Grinding is useful for removing rust and scale. Grease and oil must be removed from the joint surfaces by wiping or using degreasers. Scale, rust, dirt, oil, and grease can contaminate the weld metal and cause defects in the weld.

The efficiency and quality of welded joint also depends upon the correct preparation of the edges of the plates to be welded. It is necessary to remove all scales, rust, grease, paint, etc. from the surface before welding. The cleaning of the surface should be carried out mechanically by wire brush or power wire wheel, and then chemically by carbon tetrachloride. Proper shape to the edges of the plate should be given to produce a proper joint. The shape of edges may be plain, V-shaped, U-shaped, re-shaped, etc. The choice of various edge shapes depends upon the kind, thickness of metal to be welded. Some different types of grooves for edges of the work are shown in Figure 2.3.

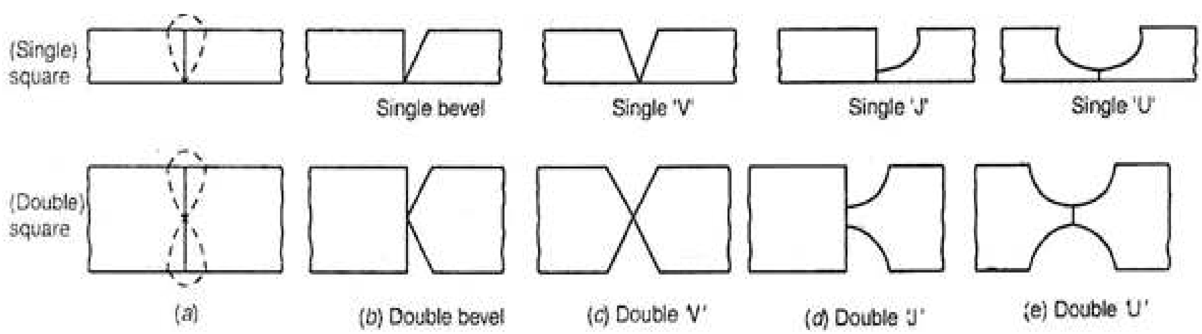



Figure 2.3.Edge Preparation

(i) Square Butt:

It is used when the thickness of the plate is from 3 to 5 mm. Both the edges to be weld should be spaced about 2 to 3mm apart as shown in Fig 2.3. (a).

(ii) Single- V-Butt:

It is used when the thickness of the plates is from 8 to 16 mm. Both the edges are beveled to form an angle of about 70° to 90°, as shown if Fig.2.3 (b).

(Iii) Double-V-Butt:

It is used when the thickness of the plates is more than 16mm and where welding can be performed on both sides of the plate. Both the edges are beveled to form a double-V, as shown in Figure 2.3 (c).

(iv) Single and Double-U Butt:

It is used when the thickness of the plate is more than 20mm. The edge preparation is difficult but the joints are more satisfactory. It requires less filler metal, as shown in the above Figure 2.3. (d) and (e).

### 2.3.3. Arc Welding weaving

Weaving is a side to side motion of the welding arc during transferring material to the joint to be welded. Weaving allows filling the joint by moving the arc, giving side to side motion for welding means moving the material in the joint to be welded. This becomes particularly necessary in laying multi-pass weld beads, where welders have to deposit wider beads, where have to deposits wider beads and thus weld over the length of units.

Weave Bead Welding Techniques involves making a weaving pattern in order to cover a larger surface area. This motion allows you to make cover welds over stringer beads, otherwise known as multi-pass welding. This technique is used when you are layering welds among one another (making multiple welds on the same seam). Below are some of the most common weave bead welding techniques used by professionals. Becoming familiar with them could prove to enhance your welding abilities. Here are some of the most common techniques:

**I. The Square Weave/C Motion**

This technique is applicable whether you are welding in the flat position or the vertical welding position.

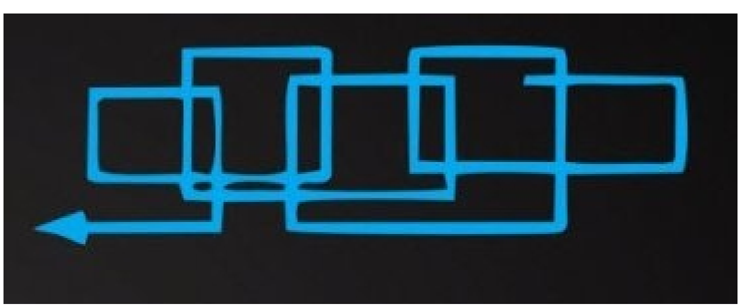


Figure 2.4. Square weave

### II. The Circular Weave

A circular motion is a good skill to possess when welding in the flat position. This technique is also great for surface welds.

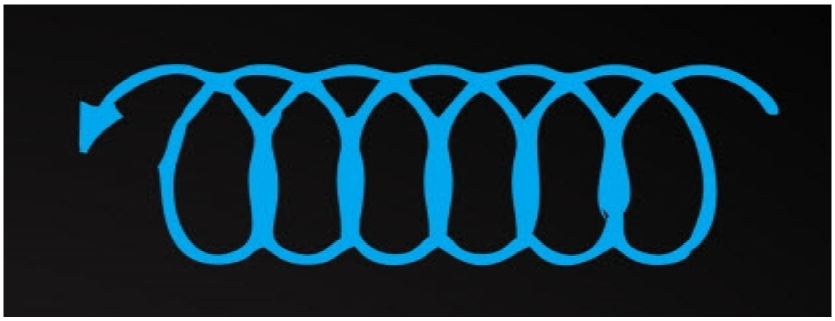


Figure 2.5.Circular weave

### III. Figure eight

The figure eight and zigzag weaving technique is a good procedure for making a cover pass when you are either in the vertical welding position or the flat welding position.

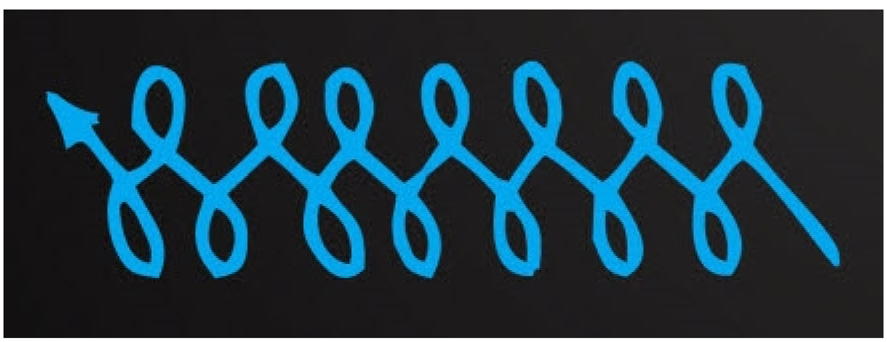


Figure 2.6. Figure eight

### IV. The J Technique

The J welding technique is most suitable for lap joints and butt welds.

Figure 2.7. J form

### V. The T Technique

This technique is best used when you find yourself in the overhead welding position or the vertical welding position.

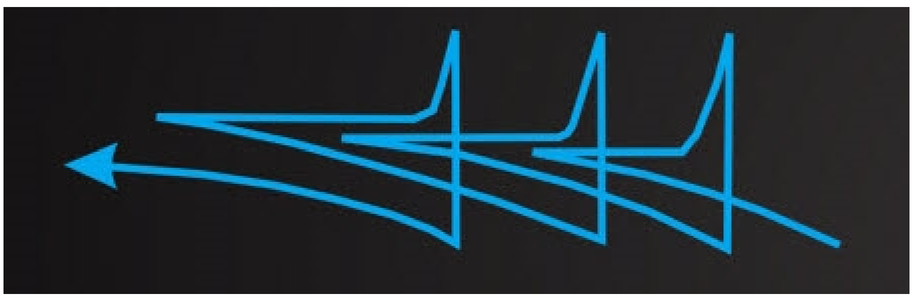


Figure 2.8. T-techniques

### VI. The Straight-Stepped Weave

This technique is usually used for multi-pass welding and/or string beads. This technique is applicable for all welding positions.

Figure 2.9. Straight-Stepped Weave

### VII. Multi Pass Welding

When welding a thick plate one will require more than just one stringer bead weld to fill the gap and make the weld strong. This requires a multi-pass welding. A multi-pass is best defined as laying several beads on the joint. Multi-pass requires the use of a weaving technique after laying a stringer bead. Making a short pause when you weave will help you avoid any undercutting and achieve perfect fusion of your material.

### VIII. Tack Welding

A tack weld is often used to maintain stability of the metal as you weld. Tack welding is also a great process for avoiding any unwanted distortion.

#### 2.3.4. Advantages and disadvantages of arc welding

**Advantages**

1. Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.).
2. Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
3. Large number of metals and alloys both similar and dissimilar can be joined by welding.
4. General welding equipment is not very costly.
5. Portable welding equipment’s can be easily made available.
6. Welding permits considerable freedom in design.
7. Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
8. Welding can also be mechanized.

**Disadvantages**

1. It results in residual stresses and distortion of the work pieces.
2. Welded joint needs stress relieving and heat treatment.
3. Welding gives out harmful radiations (light), fumes and spatter.
4. Jigs, and fixtures may also be needed to hold and position the parts to be welded
5. Edges preparation of the welding jobs is required before welding

6. Skilled welder is required for production of good welding
7. Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

## 2.4. Welding materials

### 2.4.1. Procedures for arc welding

To weld materials by manual arc welding, the following common procedures should be followed. Safety and other issues should be considered as described in the previous information sheets of this learning guide.

- Set the arc welding plant by one cable connection to electrode with electrode holder another connection for work piece with earthling clamp.
- Set the current range & electrode according to plate thickness. Ex: 6mm plate i) Current range 120Amps ii) Electrode size 3.2mm dia.
- Set the work piece for tack weld by fixing with C Clamp using suitable tack welding fixture.
- Tack the pieces at both ends by scratching or tapping method.
- Place the tack weld unit to full bead welding fixture as provided in working table.
- Deposits full bead weld with correct i) Arc lengths 3 to 5mm ii) Electrode angle 700 to 80o iii) Travel speed 150mm/min iv) uniform Movement v) Direction towards your end , usually from left to right for right handed welders.
- Reverse the joint to perform full bead on other end.
- Chip off all slag, remove spatters with using white spectacles
- Clean the bead by wire brush with using white spectacles.
- Inspect the weld bead

The basic elements involved in manual arc welding process are shown in figure 2.3 below, this process employs coatings or fluxes to prevent the weld pool from the surrounding atmosphere.

- Switch box.
- Secondary terminals
- Welding machine.
- Current reading scale.

- Current regulating hand wheel.
- Leather apron.
- Asbestos hand gloves.
- Protective glasses strap
- Electrode holder.
- Hand shield
- Channel for cable protection.
- Welding cable.
- Chipping hammer.
- Wire brush.
- Earth clamp.
- Welding table (metallic).
- 17) Job.

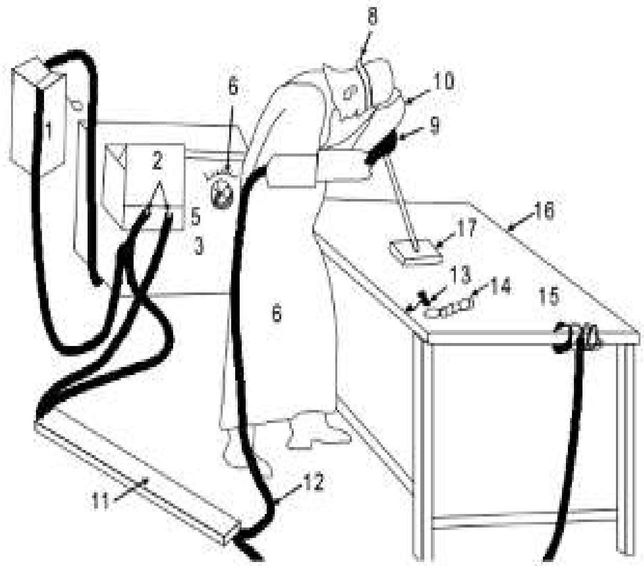



Figure 2.10.The basic elements of arc welding equipment

### 2.4.2. Welding joints

Most welding projects use at least one of the five welding joint types shown below. Understanding each welding joint type is an important part of becoming an experienced, successful welder

1. **Butt joint**

- Joins two members that meet at their edges on the same plane
- Used in applications where a smooth weld face is required
- Fillet or groove welded; groove welding requires added expertise and expense
- Improper design/welding risks distortion and residual stresses

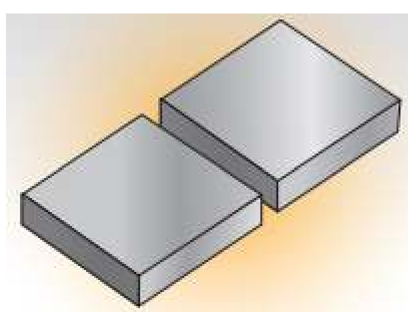
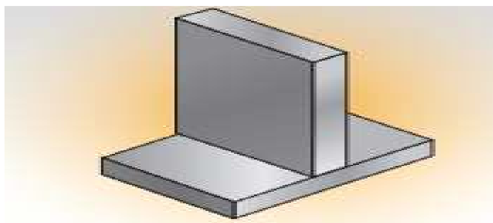


Figure 2.11.Butt joint

2. **T-joint**

- Joins two members that meet at a T-shaped angle
- Good mechanical properties, especially when welded from both sides
- Easily welded with little or no joint preparation
- Usually fillet welded, although J-grooves are possible



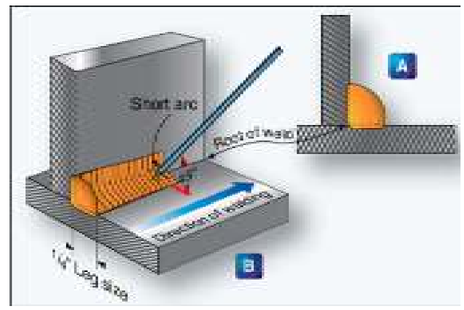
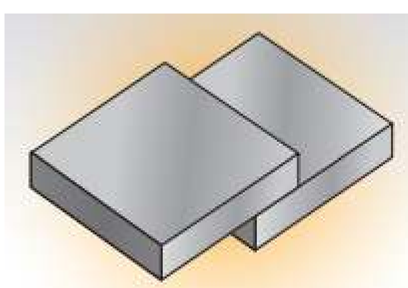



Figure 2.12.T-joint

3. **Lap Joint**

- Joins two members having overlapping surfaces
- Good mechanical properties, especially when welded from both sides
- Usually fillet welded
- Thicker material requires more overlap



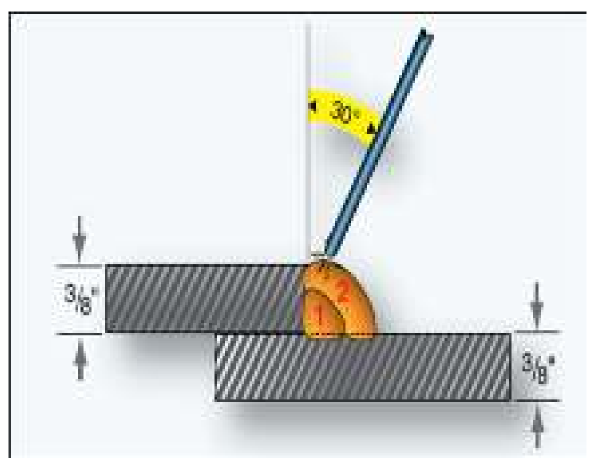



Figure 2.13. Lap joint

4. **Corner Joint**

- Joins two members that meet at an angle
- Two main types: open corner and closed corner
- Easily welded with little or no joint preparation
- Increase travel speed on light-gauge material to avoid burn-through

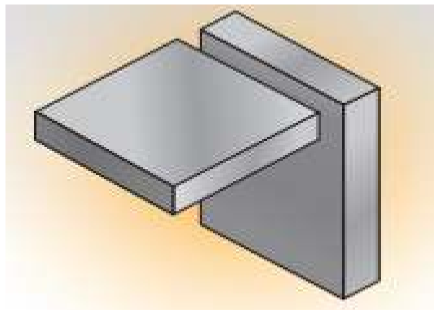


Figure 2.14. Corner joint

5. **Edge Joint**

- Joins two parallel, or nearly parallel, members
- Not recommended if either member will be subject to impact or high stresses
- Square groove is most common, but other groove configurations are possible
- Very deep penetration is impossible

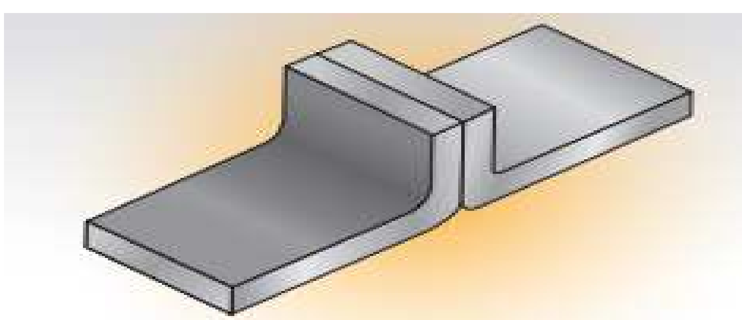


Figure 2.15. Edge joint

### 2.4.3. Welding positions

The welding positions are classified on the basis of the plane on which weld metal is deposited. The positions are flat, horizontal, vertical and overhead.

**1. Flat welding**

In flat welding, plates to be welded are placed on the horizontal plane and weld bead is also, deposited horizontally (Fig. below). This is one of most commonly used and convenient welding position. Selection of welding parameters for flat welding is not very crucial for placing the weld metal at desired location in flat welding.

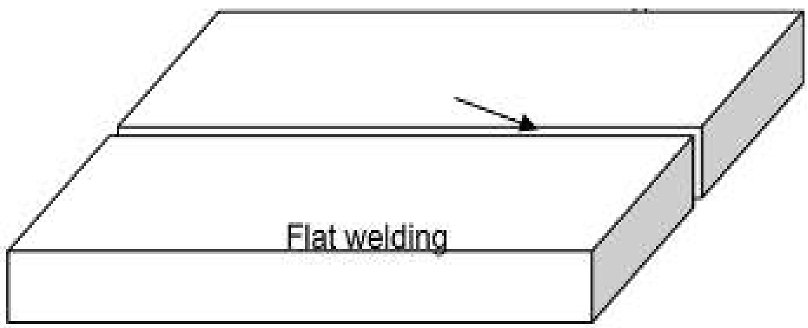



Figure 2.16.Scheme of placement of components to be welded for flat welding

There are four types of welds commonly used in flat position welding: bead, groove, fillet, and lap joint. Each type is discussed separately in the following paragraphs.

***A.* Bead Weld**

The bead weld utilizes the same technique that is used when depositing a bead on a flat metal surface. [Figure 2.17] The only difference is that the deposited bead is at the butt joint of two steel plates, fusing them together. Square butt joints may be welded in one or multiple passes. If the thickness of the metal is such that complete fusion cannot be obtained by welding from one side, the joint must be welded from both sides. Most joints should first be tack-welded to ensure alignment and reduce warping.

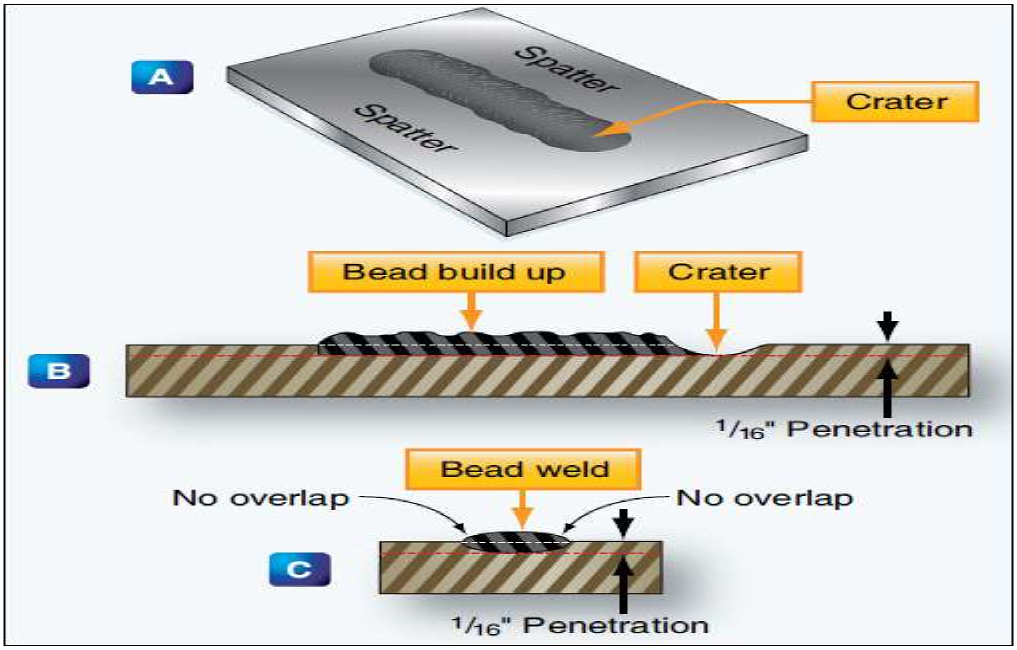



Figure 2.17. Bead weld

### *B.* Groove Weld

Groove welding may be performed on a butt joint or an outside corner joint. Groove welds are made on butt joints where the metal to be welded is ¼-inch or more in thickness. The butt joint can be prepared using either a single or double groove depending on the thickness of the plate. The number of passes required to complete a weld is determined by the thickness of the metal being welded and the size of the electrode being used.

Any groove weld made in more than one pass must have the slag, spatter, and oxide carefully removed from all previous weld deposits before welding over them. Some of the common types of groove welds performed on butt joints in the flat position are shown in Figure 2.18.

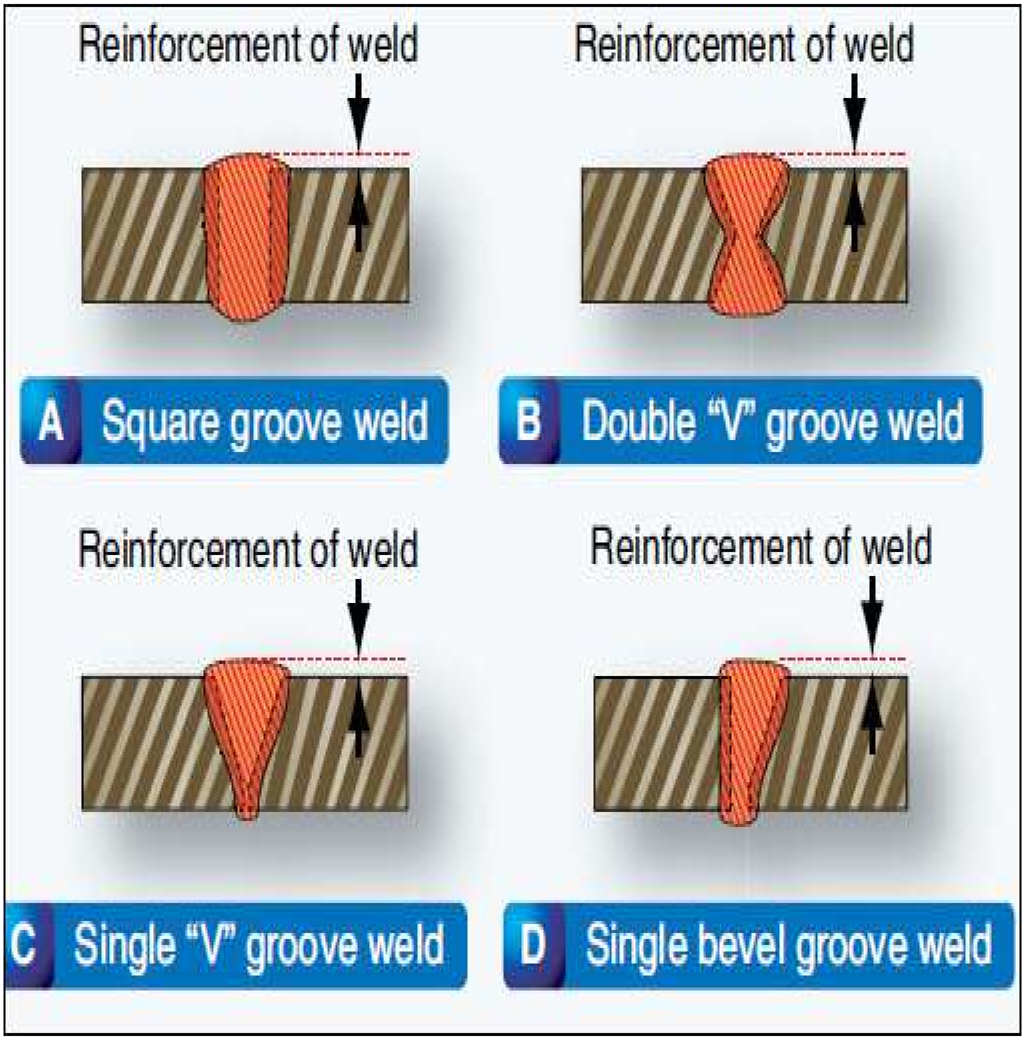



Figure 2.18. Groove weld

***C.*** **Fillet Weld**

Fillet welds are used to make tee and lap joints. The electrode should be held at an angle of 45° to the plate surface. The electrode should be tilted at an angle of about 15° in the direction of welding. Thin plates should be welded with little or no weaving motion of the electrode and the weld is made in one pass. Fillet welding of thicker plates may require two or more passes using a semicircular weaving motion of the electrode. [Figure 2.19]

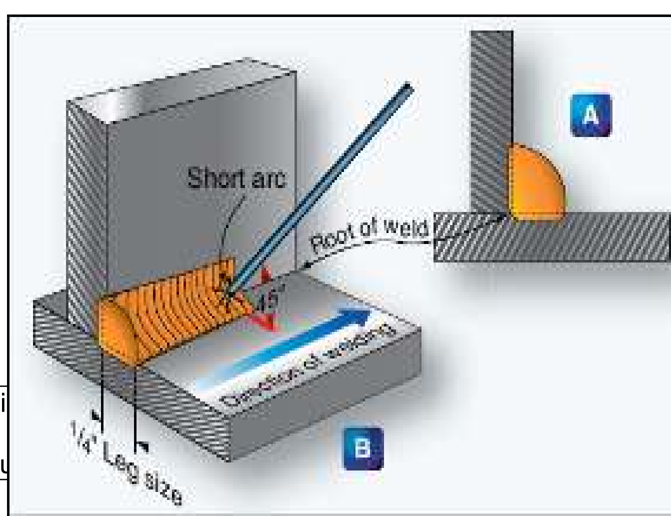


Figure 2.19. Fillet weld

### *D.* Lap Joint Weld

The procedure for making fillet weld in a lap joint is similar to that used in the tee joint. The electrode is held at about a 30° angle to the vertical and tilted to an angle of about 15° in the direction of welding when joining plates of the same thickness. [Figure 2.20]

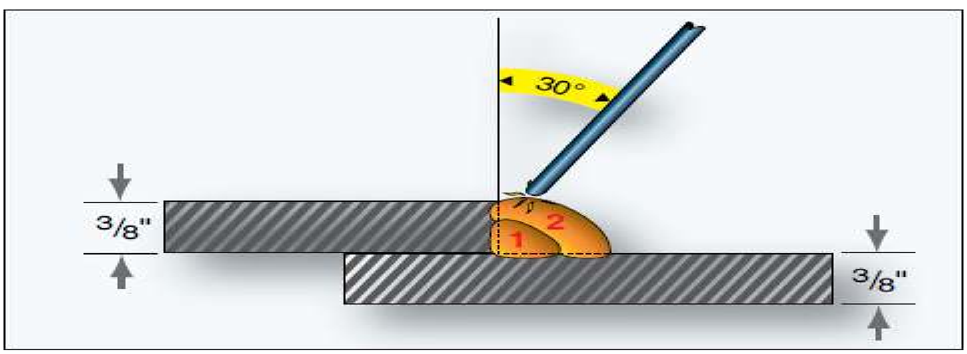



Figure 2.20.Lap joint weld

### 2. Horizontal welding

In horizontal welding, plates to be welded are placed in vertical plane while weld bead is deposited horizontally (Figure 2.21.). This technique is comparatively more difficult than flat welding. Welding parameters for horizontal welding should be selected carefully for easy manipulation/placement of weld metal at the desired location.

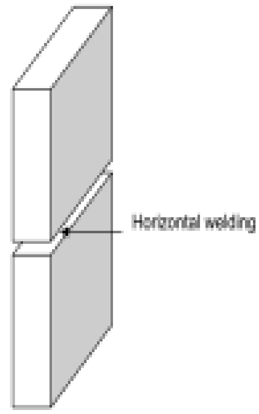



Figure 2.21Scheme of placement of components to be welded for horizontal welding

3. **Vertical welding**

In vertical welding, plates to be welded are placed on the vertical plane and weld bead is also deposited vertically (Figure 2.22.). It imposes difficulty in placing the molten weld metal from electrode in proper place along the weld line due to tendency of the melt to fall down under the influence of gravitational force. Viscosity and surface tension of the molten weld metal which are determined by the composition of weld metal and its temperature predominantly control the tendency of molten weld metal to fall down due to gravity. Increase in alloying elements/impurities and temperature of melt in general decrease the viscosity and surface tension of the weld metal and thus making the liquid weld metal more thin and of higher fluidity which in turn increases tendency of weld metal to fall down conversely these factors increase difficulty in placing weld metal at desired location. Therefore, selection of welding parameters (welding current, arc manipulation during welding and welding speed all are influencing the heat generation) and electrode coating (affecting composition of weld metal) dilution becomes very crucial for placing the weld metal at desired location in vertical welding.

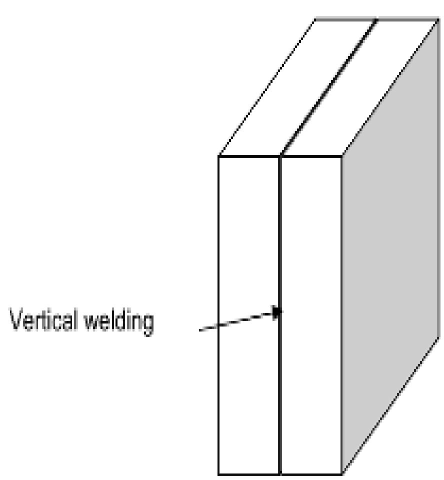


Figure 2.22. Scheme of placement of components to be welded for vertical welding

4. **Overhead welding**

In overhead welding, weld metal is deposited in such a way that face of the weld is largely downward and there is high tendency of falling down of weld metal during welding (Figure 2.23.). Molten weld metal is moved from the electrode (lower side) to base metal (upper side) with great care and difficulty hence, it imposes problems similar to that of vertical welding but with greater intensity. Accordingly, the selection of welding parameters, arc manipulation and welding consumable should be done after considering all factors which can decrease the fluidity of molten weld metal so as to reduce the weld metal falling tendency. This is most difficult welding position and therefore it needs great skill to place the weld metal at desired location with close control.

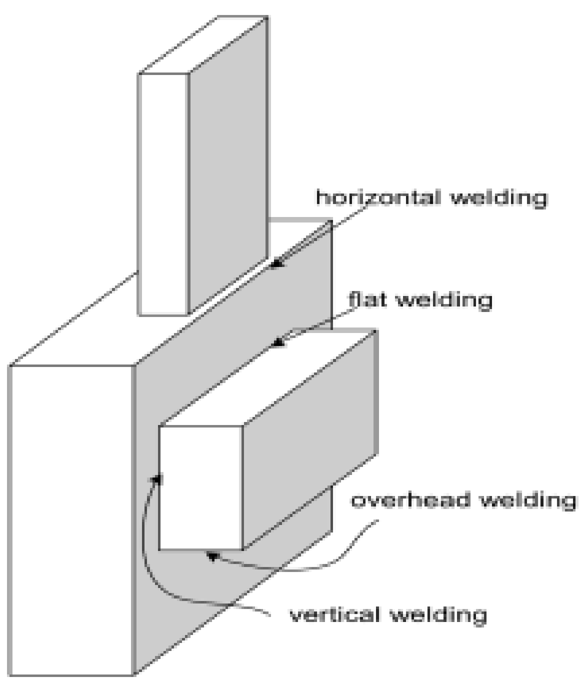


Figure 2.23. Scheme of placement of components to be welded for different types of welding positions including overhead welding

After preparing and setting the materials, the next step is welding and producing output as indicated in the following figure 2.24.

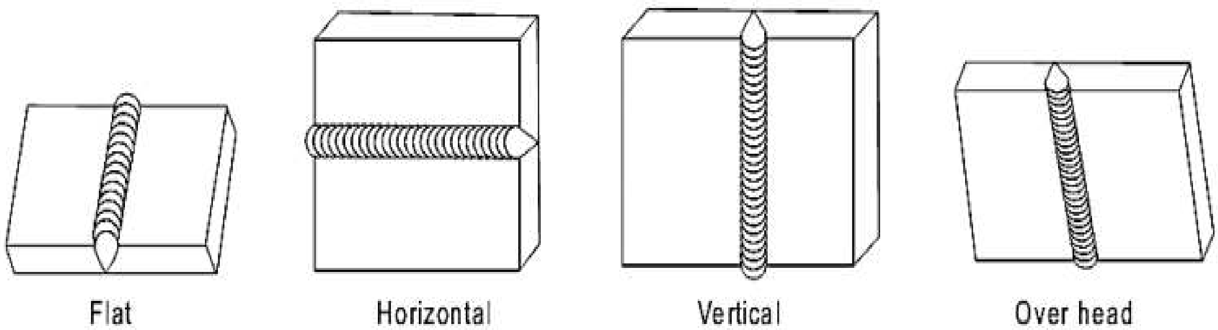



Figure 2.24. Different welding positions applied on butt joint.

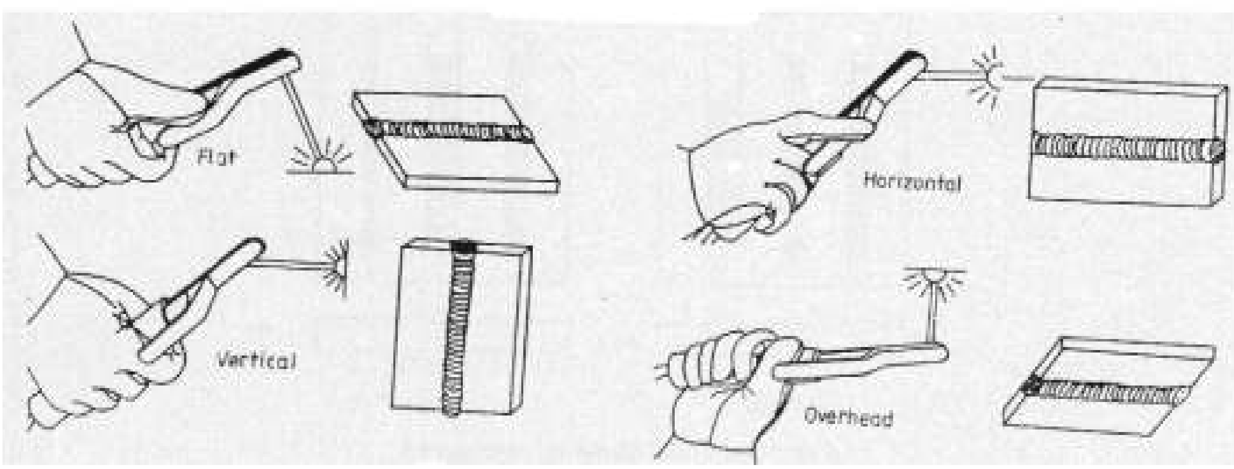



Figure 2.25.Application of butt joint welding at different positions

## 2.5. Clean weld seamor joints

### 2.5.1. Clean welding seams

Cleaning is necessary before welding, during welding (inter-pass) and is usually essential after welding in order to ensure maximum corrosion resistance. Each welding run must be thoroughly cleaned to remove slag and spatter before proceeding with the next run. The cleaning method used (chipping, brushing, grinding) will depend on the welding process, bead shape, etc. but care should be taken to see that the weld area is not contaminated in the process. Any cleaning equipment should be suitable for stainless steel and kept for that purpose. During welding, a gas purge on the reverse side may be advantageous. After welding, weld spatter, flux, scale, arc strikes and the overall heat discoloration should be removed. This can involve grinding and polishing, blasting and brushing with a stainless steel wire brush, or use of a descaling solution or paste. The preferred procedure is usually dictated by end use. Grinding and dressing is to be carried out with iron-free brushes, abrasives, etc. and should not be so heavy as to dis-colour and overheat the metal. Rubber and resin bonded wheels are satisfactory. Wheels should be dressed regularly to prevent those becoming loaded thereby producing objectionable scratches. In any blasting process steel shot shall not be used.

## 2.6. Measurement of OHS

### 2.6.1. Occupational health and safety

To achieve safe working conditions in the metal fabrication and welding industry, all personnel should be able to recognize the hazards which apply to their particular occupation. Welding operators must also know the correct operating procedures for the equipment.

An operator can be subjected to many safety hazards associated with the industry. As with any other industrial worker, they may be injured through incorrect lifting practices, falling or tripping, or incorrect use of hand tools and machines. The operator will also encounter particular hazards associated with welding. A clean, tidy workplace, free from combustible materials, is an essential requirement for the safety of welding personnel.

Additionally, others working in the vicinity of welding operations are at risk from hazards such as electrocution, fumes, radiation, burns or flying slag and noise. They too must be protected if their health and safety is not to be put at risk.

### 2.6.2. Safety Recommendations for Arc Welding

The beginner in the field of arc welding must go through and become familiar with these general safety recommendations which are given as under

1. The body or the frame of the welding machine shall be efficiently earthed. Pipe lines containing gases or inflammable liquids or conduits carrying electrical conductors shall not be used for a ground return circuit All earth connections shall be mechanically strong and electrically adequate for the required current.

2.Welding arc in addition to being very is a source of infra-red and ultra-violet light also; consequently the operator must use either helmet or a hand-shield fitted with a special filter glass to protect eyes

3. Excess ultra-violet light can cause an effect similar to sunburn on the skin of the welder

4. The welder's body and clothing are protected from radiation and burns caused by sparks and flying globules of molten metal with the help of the following

- Gloves protect the hands of a welder.
- Leather or asbestos apron is very useful to protect welder's clothes and his trunk and thighs while seated he is doing welding.
- For overhead welding, some form of protection for the head is required
- Leather skull cap or peaked cap will do the needful.
- Leather jackets and 1ather leggings are also available as clothes for body protection.
- Welding equipment shall be inspected periodically and maintained in safe working order at all times.
- Arc welding machines should be of suitable quality. All parts of welding set shall be suitably enclosed and protected to meet the usual service conditions.

### 2.6.3. Welding hazards and risks

The hazards in manual electric arc welding operation can be broadly grouped into the following major categories:

**A.** Fire and explosion hazards;
**B.** Electrical hazards;
**C.** Physical hazards;
**D.** Respiratory hazards; and
**E.** Other related hazards.

### A. Fire and explosion hazards

Fire and explosion hazards in manual electric arc welding operation are mainly caused by the high temperature of the electric arc used or the hot slag and sparks of molten metal produced in the process. These hazards include:

1. Fires caused by sparks or globules of molten metal generated during the welding work igniting the combustible material in the vicinity of the work;
2. Fires caused by the hot welding electrode that igniting the combustible material in the vicinity of the work;
3. Fires and explosions caused by the ignition of critical mixtures of gases, volatile flammable liquids or combustible dusts with air;
4. Fires and explosions arising from the ignition of the combustible/ flammable residue in the work piece; and
5. Fires caused by bad contact or loose connections of cables and welding equipment, and faulty electrical connections or insulation.

### B. Electrical hazards

In manual electric arc welding operations, the major electrical hazard is electric shock. The exposed welding electrode that becomes live when the welding equipment is in use poses obvious electric shock hazard to the welding worker. Any defective welding equipment or improper electrical wiring also poses electric shock hazard to the welding worker or other workers in the vicinity.

### C. Physical hazards

Physical hazards of manual electric arc welding operation are mainly:

- Thermal

i. Skin or eye burns from the arc, sparks and spatter;
ii. Thermal stress from prolonged arc welding operation especially in confined spaces or in hot and humid environment.

- Radiations

Ultraviolet (UV), visible light and infrared (IR) exposure can cause "Welder's flash", eye burn, skin burns (sun burns) and skin cancer;

**D.** Respiratory hazards

- Fumes and other particulates

Welding produces fumes that may contain fluorides and oxides of metals, including lead, cadmium, manganese, zinc, iron, molybdenum, cobalt, vanadium, nickel, chromium, beryllium, aluminum, copper, magnesium, tin, titanium and tungsten. Inhalation of some metal oxides may give rise to metal fume fever and others to irritation of the respiratory tract.

**i.** Fumes generally contain particles from the electrode and the material being welded;

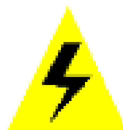
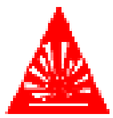
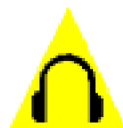
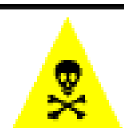
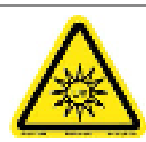
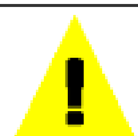
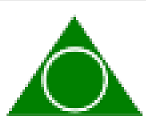
**ii.** Fumes from other finishes or coatings that have been applied to the metal.

**E. Other related hazards**

These are hazards specific to an individual manual electric arc weldingoperation. These include, but not limited to,

- Hazards related to the access to and working at high levels such asfalling from height and the loss of stability of structures used to accesshigh levels;
- Tripping hazards due to tangling welding cables;
- Hazards due to the exhaust fumes from engine-driven electric generator and the storage of fuel;
- Hazards from changes in weather conditions when welding in the open ground;
- Noise hazards from high pitch screaming or hissing from power source or associated equipment, and banging noise from grinding and chipping, etc.; and
- Musculoskeletal problems resulting lifting heavy objects, repetitive motions and long periods of customary postures.

Table 2.1 Potential health & safety hazards signs

| HAZARD | | TO PROTECT YOURSELF |
|---|---|---|
| **PINCH POINTS**<br>There are gears and exposed moving parts on machinery. |  | Use LOCK-OUT procedures when performing maintenance or conducting any work within 12" of an exposed pinch point.<br>NEVER put your hands or feet near an exposed pinch point or gears! |
| **ELECTRICAL HAZARD** |  | Ensure all electrical equipment and machines have plugs and wires that are in good condition. |
| **EXPLOSIVE** |  | Make sure cylinders are stored and handled correctly.<br>Proper grounding must be used. |
| **HIGH SOUND LEVELS**<br>Sound levels exceed 85 dB |  | **HEARING PROTECTION** is required when working in designated areas. |
| **EXPOSURE** |  | Understand the chemical(s) you are working in the vicinity of. Consult the MSDS and wear the appropriate PPE. |
| **UV Light** |  | Ensure you are taking safety means to protect yourself from UV rays while welding |
| **FOOT INJURY** |  | Approved protective footwear is needed when there is the risk of foot injury due to slipping, uneven terrain, abrasion, crushing potential, temperature extremes, corrosive substances, puncture hazards, electrical shock and any other recognizable hazard |
| **COMPRESSED GASES** |  | Do not<br>• drop<br>• keep near heat |
| **FIRE**<br>Due to flammable liquids, gases or combustible dusts |  | Ensure that your work area is clear of combustible materials that could start a fire as a result of welding sparks. |
| **FOOT INJURY**<br>Falling objects |  | The appropriate ASTM or CSA approved footwear must be worn when job hazard analysis shows it is needed. |

## 2.7. Application of personal protective equipment

Protective equipment is at the heart of any welding safety plan. Where there is exposure to sharp or heavy falling objects or a hazard of bumping in confined spaces, hard hats or head protectors must be used. For welding and cutting overhead or in confined spaces, steel-toed boots and ear protection must also be used.

### 2.7.1. Welding Protective Clothing

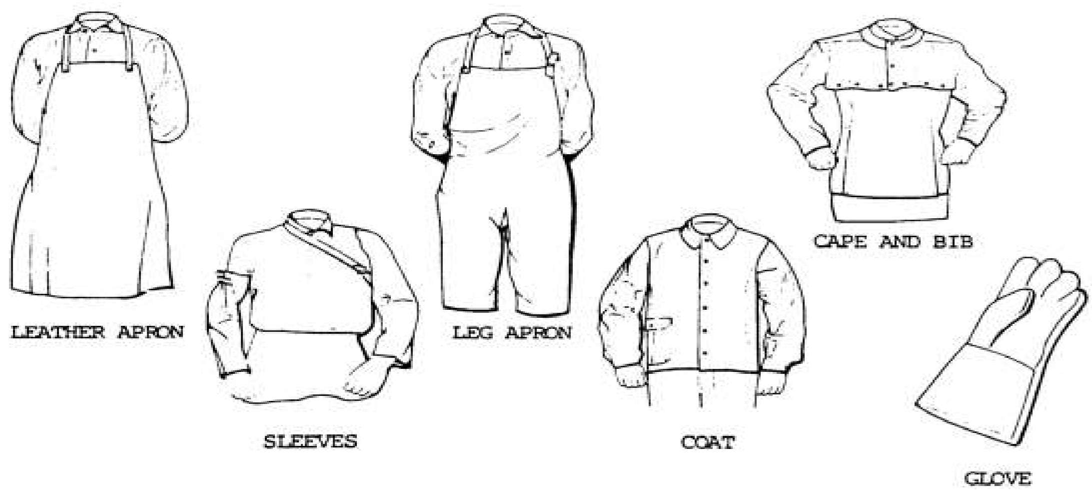
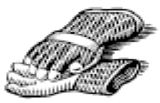



Figure 2.26.Protective close

Protective Clothing includes welding gloves, coat, sleeves, and leg protection. Personnel exposed to the hazards created by welding, cutting, or brazing operations shall be protected by personal protective equipment in accordance with OSHA standards.

### 2.7.2. Personal protective equipment

| | |
|---|---|
|  | Safety glasses must be worn at all times in work area! |
|  | Respirator with HEPA filters must be worn when working with asbestos containing materials. Workers must be fit tested prior to performing any asbestos work. |
|  | Work Boots must be worn at all times when working in an area where there is risk of serious foot injury due materials falling onto the foot. |
|  | Welding work gloves should be worn when there is a risk of hand injury during the course of work tasks. |
|  | Hard hats must be worn when working in an environment where there is a risk of objects falling from above or where there is a high risk of striking your head on objects. |

| | |
|---|---|
|  | Welding helmets must be kept in good shape and have protective lenses meeting shade selection requirements for the task. |
|  | Protective clothing must be worn whenever cutting, welding and grinding is done. This includes welding jacket, welding gloves, and respirator is required. |

### 2.7.3. Welding safety tools

During welding, arc produces fumes, sparks, infrared or ultraviolet rays and slag, which are dangerous for life, so proper utilization of safety devices, can prevent the welder from those hazards. These safety devices are described.

1. Gloves: these must be made of leather and should be the gauntlet style, covering your Forearms.

Figure 2.27. Gloves

2. Aprons: are flame retardant outfits worn by a welder to protect the under clothing and the body from the sparks, the molten metal and the hot metal being welded.

Figure 2.28. Apron

3. Welding goggles: are used to protect the eyes from the rays of light emitted by the flame and the pool of molten metal, and from flying sparks.

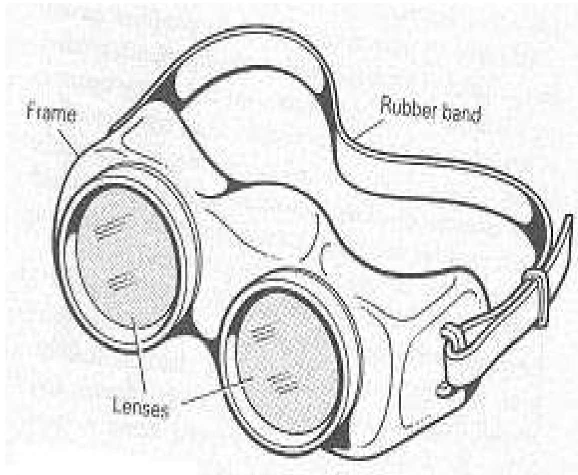



Figure 2.29. Welding goggles

4. Welding shield: these are available as a hand held shield or a head shield /helmet/, which leaves both hands free.

Figure 2.30. Helmet

a) Welding hand shields: are used to protect the face during welding.

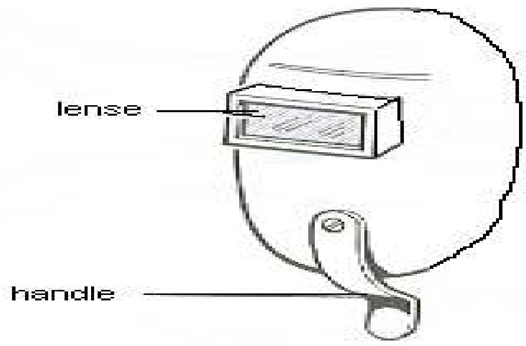



Figure 2.31. Welding hand shield

## Self-check: Two

**Instruction one: choose the correct answer**

1. The consumable electrodes provide
   A. Gas protection B. Adding element to change mechanical properties C. A and B D.none
2. Best metal surface should free from
   A. weld B. oil &Grease C. oxide scale D. All except A
3. Common welding joints

A. Edge & corner B. Butt &T –joint C. Lap joint D. All of the above

4. Factors to be considered during selection of electrode are:

A. Properties of base metal B. Electrode diameter

C. Joint design &Joint up D. Welding position E. All of the above

5. In symbol E-7018 E-stand for

A. Tensile strength B. Electrode C. Welding position D. All of the above

**Instruction two: Matching**

**A** **B**

| | |
|---|---|
| 1. A metallic core is coated with some suitable material | A. Double-V-Butt |
| 2. In electrode identification the first and second digit indicates | B. single V-butt |
| 3. It is used when the thickness of the plate is from 3 to 5 mm | C. Square butt |
| 4. It is used when the thickness of the plates is from 8 to 16 mm | D. Tensile testing |
| 5. It is used when the thickness of the plates is more than 16mm | E. Coated electrodes |

## Operation sheet

**OPERATION TITLE: Butt weld in flat position**

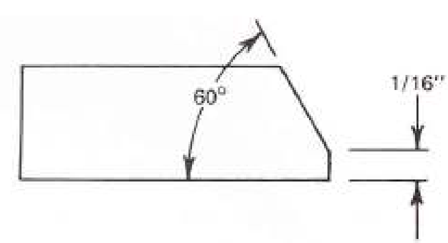
**PURPOSE: To perform the butt welding in flat position**

**Conditions or situations for the operations:**

**Equipment tools and materials:** Standard AC or DC welding machine Helmet Gloves Chipping hammer Safety glasses Wire brush Necessary protective clothing 8mm mild steel plate E-6013 electrodes Two pieces 8mm mild steel plate

**Procedure:**

1. Grind one edge of each plate to form a 60-degree included angle. Grind a 1/16-inch land at the bottom of the bevel,.



2. Tack weld the two plates together on a flat plane, so that the bevels fit together to form a V.
3. Beginning at the left side of the V, weld a pass all the way across the joint with a 1/8-inch. E-6Ol 3 electrode.

4. Chip and brush the weld, then examine the root pass. The edges of the two plates should be completely fused together with no un welded edges.

*5.* When satisfactory penetration of the root pass has been accomplished, fill the remaining V of the weld, using *E*-6013 electrodes.

6. Chip and brush the weld.

Note: Save the welded plate for testing later.

**Precaution**: The welder must have face and eye protection when chipping welds. Open the window in the hood but keep the hood down when chipping or brushing welds. The metal is hot. Handle it with pliers

**Quality criteria:** bead size and appearance

## Lap Test: Practical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4 hour.

Task 1. Butt weld in flat position

Task 2. Clean work area.

Task 3. Applying OHS measures

## Unit Three: Quality Assurance and Clean Up In Welding Process

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Clean and inspect welding seams
- Joints Measurement
- Clean and maintain welding equipment and work area
- Post-welding treatments

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform to Clean and inspect welding seams
- Identify joints measurement
- Perform clean and maintain welding equipment
- Identify the mechanism of Post-weld treatments

## 3.1. Clean and inspect welding seams

### 3.1.1. Clean welding seams

In the welding seams the slag or flux remaining after a pass, shall be removed before applying the next covering pass. After the final pass all slag and weld spatter shall be removed. Arc strikes shall be removed by grinding or other suitable means. Cracks or blemishes caused by arc strike shall be ground to a smooth contour and examined visually to assure complete removal.

### 3.1.2. Welding Defects

The lack of training to the operator or careless application of welding technologies may cause discontinuities in welding. In joints obtained by fusion welding, the defects such as porosity, slag inclusion, solidification cracks etc., are observed and these defects deteriorates the weld quality and joint properties. Common weld defects found in welded joints. These defects may result in sudden failures which are unexpected as they give rise to stress intensities. The common weld defects include:

1. Porosity
2. Lack of fusion
3. Inclusions
4. Cracking
5. Undercut

**1. Porosity**

Occurs, when the solidifying weld metal has gases trapped in it, the presence of porosity in most of the welded joints is due to dirt on thesurface of the metal to be welded or damp consumables. It is found in the shape of sphere or as elongated pockets. The region ofdistribution of the porosity is random and sometimes it is moreconcentrated in a certain region. By storing all the consumables in dryconditions and degreasing and cleaning the surface before welding,porosity can be avoided.

2. **Lack of Fusion**

Due to too little input or too slow traverse of the welding torch, lack of fusion arises. By increasing the temperature, by properly cleaning theweld surface before welding and by selecting the appropriate joint designand electrodes, a better weld can be obtained. On extending the fusionzone to the thickness of the joints fully, a good quality joint can be obtained.

3. **Inclusions**

Due to the trapping of the oxides, fluxes and electrode coating materialsin the weld zone the inclusions are occurred. Inclusions occur whilejoining thick plates in several runs using flux cored or flux coated rodsand the slag covering a run is not totally removed after every run andbefore the next run starts. By maintaining a clean surface before the runis started, providing sufficient space for the molten weld metal betweenthe pieces to be joined, the inclusions can be prevented.

4. **Cracking**

Due to thermal shrinkage, strain at the time of phase change, cracksmay occur in various directions and in various locations in the weld area.Due to poor design and inappropriate procedure of joining high residualstresses, cracking is observed. A stage-wise pre-heating process andstage-wise slow cooling will prevent such type of cracks. This can greatly increase the cost of welded joints. Cracks are classified as hot crackingand hydrogen induced cracking. A schematic diagram of centerline cracks shown below figure 3.1.

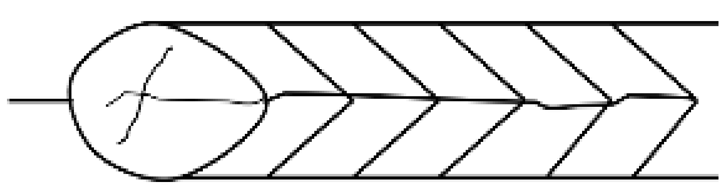


Figure 3.1. Schematic diagram of centerline crack

The cracking can be minimized by preferring fillers with low carbonand low impurity levels. The solidification cracking can be avoided byreducing the gaps and cleaning the surface before welding.

5. **Undercutting**

The undercut is caused due to incorrect settings or using improperprocedure. Undercutting can be detected by a naked eye and the excess.

- To produce quality weld joints, it is necessary to keep an eye on what is being done in three different stages of the welding
- Before welding such as cleaning, edge preparation, baking of electrode etc. to ensure sound and defect free weld joints
- During welding various aspects such as manipulation of heat source, selection of input parameters (pressure of oxygen and fuel gas, welding current, arc voltage, welding speed, shielding gases and electrode selection) affecting the heat input and so melting, solidification and cooling rates besides protection of the weld pool from atmospheric contamination
- After welding steps, if any, such as removal of the slag, peening, post welding treatment.
- Selection of optimal method and parameters of each of above steps and their execution meticulously in different stages of production of a weld joint determine the quality of the weld joint.

### 3.1.3. Inspection and test in weld joint

Inspection is mainly carried out to assess ground realties in respect of progress of the work or how meticulously things are being implemented. Testing helps to: a) assess the suitability of the weld joint for a particular application and b) to take decision on whether to go ahead (with further processing or accept/reject the same) at any stage of welding and c) quantify the performance parameters related with soundness and performance of weld joints. Testing methods of the weld joint are broadly classified as destructive testing and non-destructive testing. Destructive testing methods damage the test piece to more or less extent. The extent of damage on (destructive) tested specimens sometime can be up to complete fracture (like in tensile or fatigue testing) thus making it un-useable for the intended purpose while in case of non-destructive tested specimen the extent of damage on tested specimen is either none or negligible which does not adversely affect their usability for the intended purpose in anyways.

Weld joints are generally subjected to destructive tests such as hardness, toughness, bend and tensile test for developing the welding procedure specification and assessing the suitability of weld joint for a particular application. Visual inspection reflects the quality of external features of a weld joint such as weld bead profile indicating weld width and reinforcement, bead angle and external defects such as craters, cracks, distortion etc. only.

### 3.1.4.Welding Quality Control

In the fabrication or repair of equipment, tests are used to determine the quality and soundness of the welds. Many different tests have been designed for specific faults. The type of test used depends upon the requirements of the welds and the availability of testing equipment. In this section, nondestructive and destructive testing are briefly discussed.

***1.*** **Nondestructive Testing**

Nondestructive testing is a method of testing that does not destroy or impair the usefulness of a welded item. These tests disclose all of the common internal and surface defects that can occur when improper welding procedures are used. NDT is basically an examination that is performed on an object of any type, size, shape or material to determine the presence or absence of discontinuities, or to evaluate other material characteristics without affecting the physical properties and causing no structural damage to it.

Inherent flaws in the work piece of a machine such as cracks, pores and micro cavities may result is a fatal failure of the machine, thus affecting the production. Hence it is very important to detect the flaws in the part. Destructive method of testing may not help for machine parts due to structural damage occurring with it. Thus, Non Destructive Testing is a method used to test a part for the flaws without affecting the physical properties and causing no structural damage to it (Huang et al 2001). There are many methods of NDT techniques available for testing.  Six most common NDT/ non- destructive test/methods

1. Visual

2. Ultrasonic Test
3. Liquid Penetration Test
4. Eddy Current Test
5. Magnetic Particle Test
6. X-ray and Gamma ray Radiography Test

**Uses of NDT**

- Flaw Detection and Evaluation
- Leak Detection, Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination

**A. Visual Inspection**

Visual inspection is usually done automatically by the welder as he completes his welds. This is strictly a subjective type of inspection and usually there are no definite or rigid limits of acceptability. The welder may use templates for weld bead contour checks. Visual inspections are basically a comparison of finished welds with an accepted standard. This test is effective only when the visual qualities of a weld are the most important.

**B. Ultrasonic testing**

Ultrasonic inspection of testing uses high-frequency vibrations or waves to locate and measure defects in welds. It can be used in both ferrous and nonferrous materials. This is an extremely sensitive system and can locate very fine surface and subsurface cracks as well as other types of defects, all types of joints can be tested.

This process uses high-frequency impulses to check the soundness of the weld. In a good weld, the signal travels through the weld to the other side and is then reflected back and shown on a calibrated screen. Irregularities, such as gas pockets or slag inclusions, cause the signal to reflect back sooner and will be displayed on the screen as a change in depth. When you use this system, most all types of materials can be checked for defects. Another advantage of this system is that only one side of the weld needs to be exposed for testing.

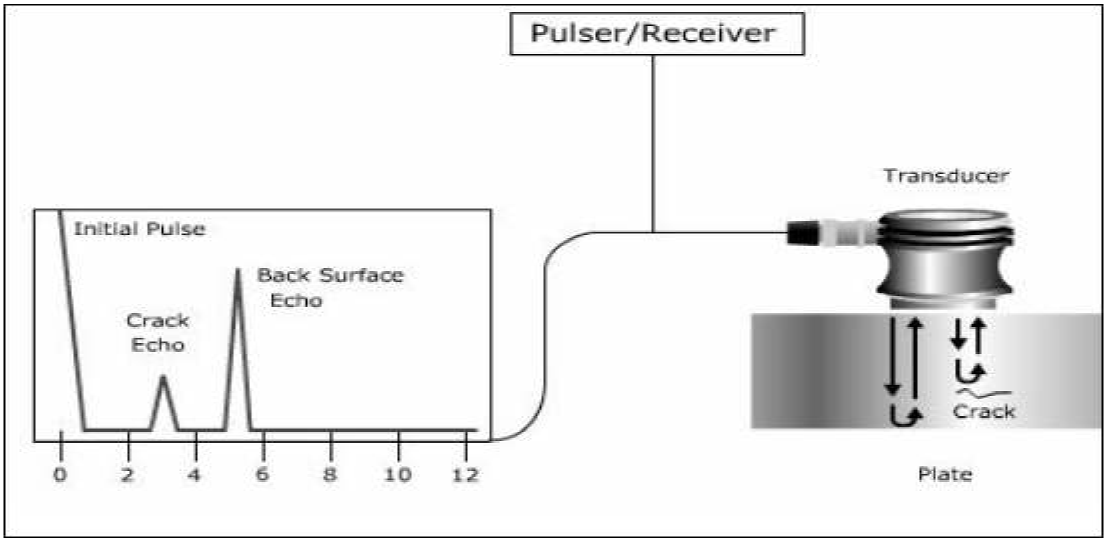



Figure 3.2. Typical ultrasonic inspection system

C. **Eddy Current Testing**

Eddy current is another type of testing that uses electromagnetic energy to detect faults in weld deposits and is effective for both ferrous and nonferrous materials. Eddy current testing operates on the principle that whenever a coil carrying a high-frequency alternating current is placed next to a metal, an electrical current is produced in the metal by induction. This induced current is called an eddy current.

The test piece is exposed to electromagnetic energy by being placed in or near high-frequency ac current coils. The differences in the weld cause changes in the impedance of the coil, and this is indicated on electronic instruments. When there are defects, they show up as a change in impedance, and the size of the defect is shown by the amount of this change.

***2.*** **Destructive Testing**

In destructive testing, sample portions of the welded structures are required. These samples are subjected to loads until they actually fail. The failed pieces are then studied and compared to known standards to determine the quality of the weld. The most common types of destructive testing are known as *free bend, guided bend, nick-break, and impact; fillet welded joint, etching,* and *tensile* testing. The primary disadvantage of destructive testing is that an actual section of a weldments must be destroyed to evaluate the weld. This type of testing is usually used in the certification process of the welder.

### A. Tensile test

Tensile properties of the weld joints namely yield and ultimate strength and ductility (%age elongation, %age reduction in area) can be obtained either in ambient condition or in special environment (low temperature, high temperature, corrosion etc.) depending upon the requirement of the application using tensile test which is usually conducted at constant strain rate (ranging from 0.0001 to 10000 mm/min). Tensile properties of the weld joint are obtained in two ways a) taking specimen from transverse direction of weld joint consisting base metal-heat affected zone-weld metal-heat affected zone-base metal and b) all weld metal specimen as shown in figure 3.3:

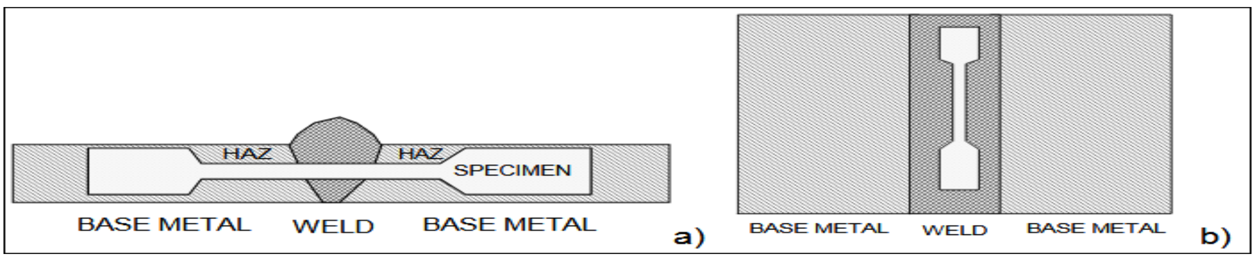



Figure 3.3. Schematic of tensile specimens from a) transverse section of weld joints and b) all weld specimen

Tensile test results must be supported by respective engineering stress and strain diagram indicating modulus of elasticity, elongation at fracture, yield and ultimate strength (figure 3.4.). Tests results must include information on following point about test conditions

- Type of sample (transverse weld, all weld specimen)
- Strain rate (mm/min)
- Temperature or any other environment in which test was conducted if any
- Topography, morphology, texture of the fracture surface indicating the mode of fracture and respective stress state.

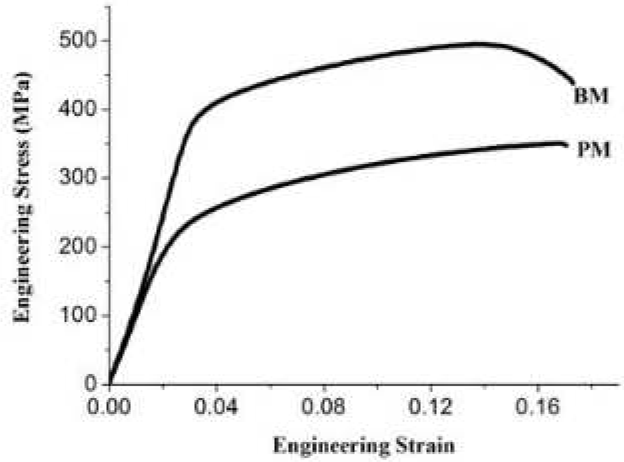



Figure 3.4. Typical stress stain diagram for AA 7039 in as received (BM) and friction stir processed (PM) condition.

### B. Bend test

Bend test is one of the most important and commonly used destructive tests to determine the ductility and soundness (for the presence porosity, inclusion, penetration and other macro-size internal weld discontinuities) of the weld joint produced using under one set of welding conditions. Bending of the weld joint can be done from face or root side depending upon the purpose i.e. whether face or root side of the weld is to be assessed. The root side bending shows the lack of penetration and fusion if any at the root. Further, bending can be performed using simple compressive/bending load and die of standard size for free and guided bending respectively (figure 3.5 and 3.6). Moreover, free bending can be face or root bending while guided bending is performed by placing the weld joint over the die as needs for bending is better and controlled condition as shown in figure 3.5.

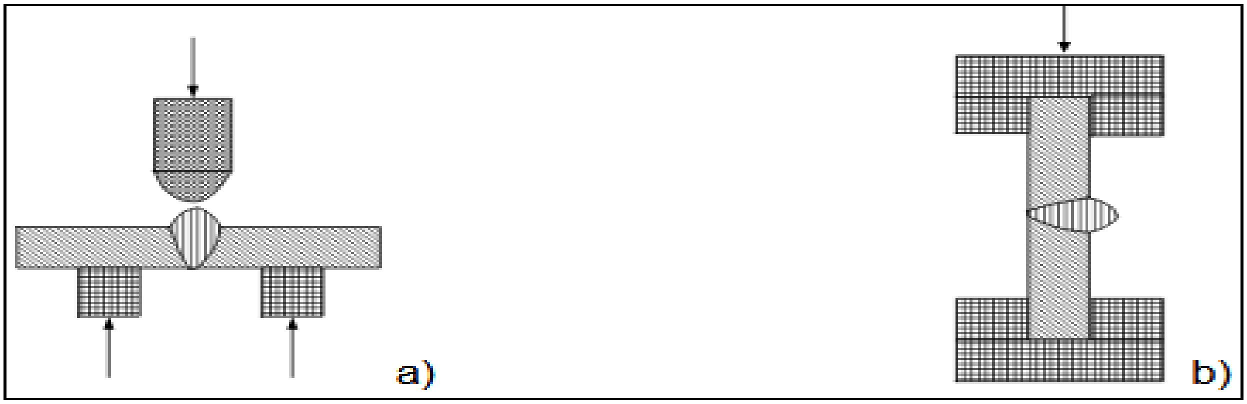



Figure 3. 5. Schematics of free bend tests

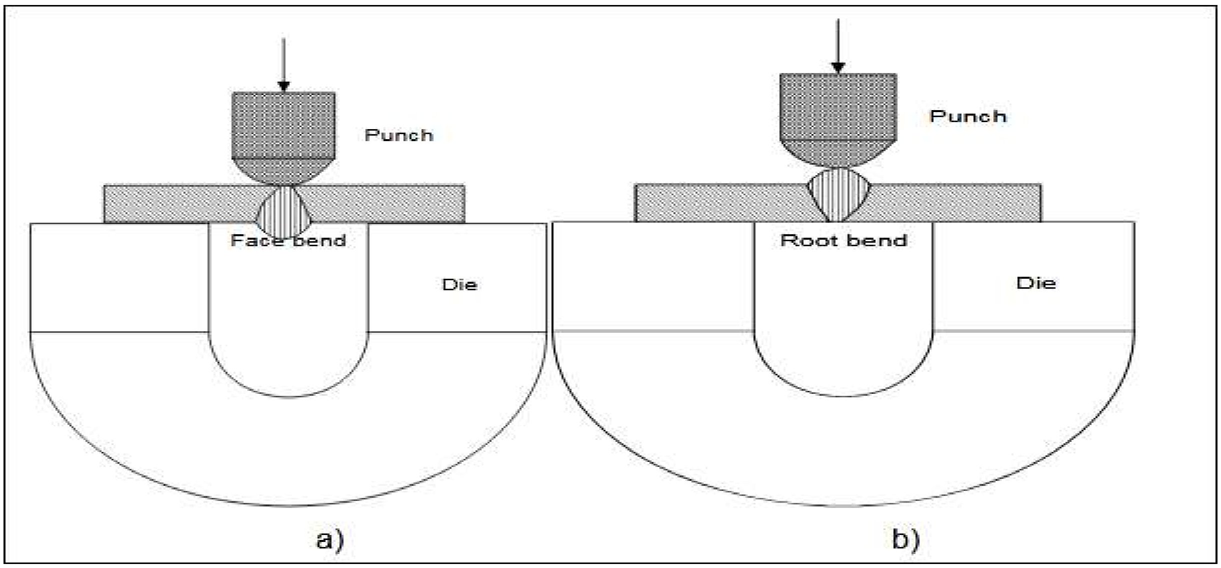
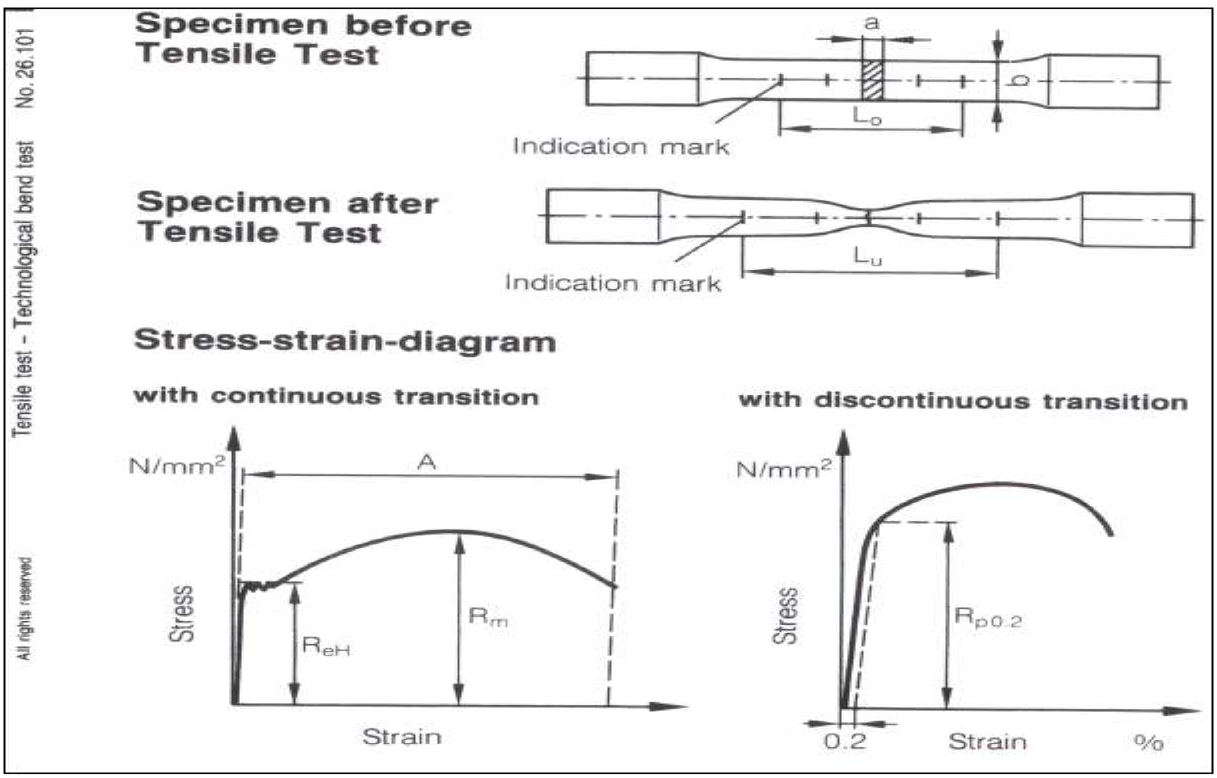


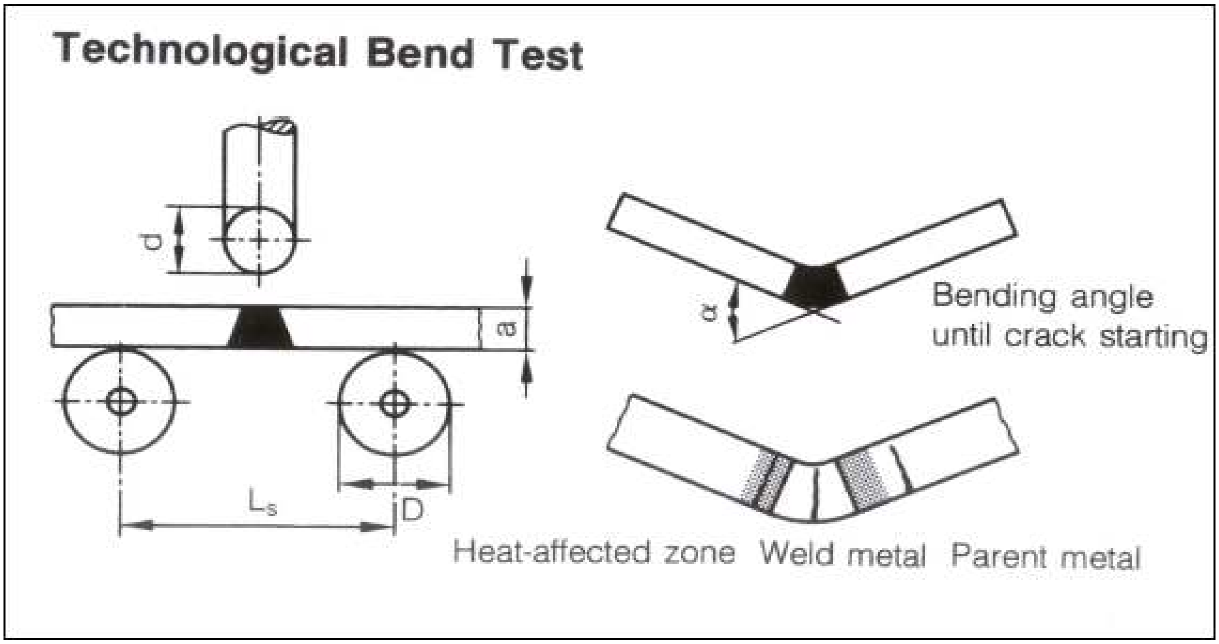

Figure 3.6.Schematics of guided bend tests a) face bend and b) root bend

For bend test, the load increased until cracks start to appear on face or root of the weld for face and root bend test respectively and angle of bend at this stage is used as a measured of ductility of weld joints. Higher is bend angle (needed for crack initiation) greater is ductility of the weld. Fracture surface of the joint from the face/root side due to bending reveals the presence of internal weld discontinuities if any.

### C. Hardness test

Hardness is defined as resistance to indentation and is commonly used as a measure of resistance to abrasion or scratching. For the formation of a scratch or causing abrasion, a relative movement is required between two bodies and out of two one body must penetrate/indent into other body. Indentation is the penetration of a pointed object (harder) into other object (softer) under the external load. Resistance to the penetration of pointed object (indenter) into the softer one depends on the hardness of the sample on which load is applied through the indenter. All methods of hardness testing are based on the principle of applying the standard load through the indenter (a pointed object) and measuring the penetration in terms of diameter/diagonal/depth of indentation (figure 3.7). High penetration of an indenter at a given standard load suggests low hardness. Various methods of hardness testing can be compared on the basis of following three criteria 1) type of indenter, 2) magnitude of load and 3) measurement of indentation.





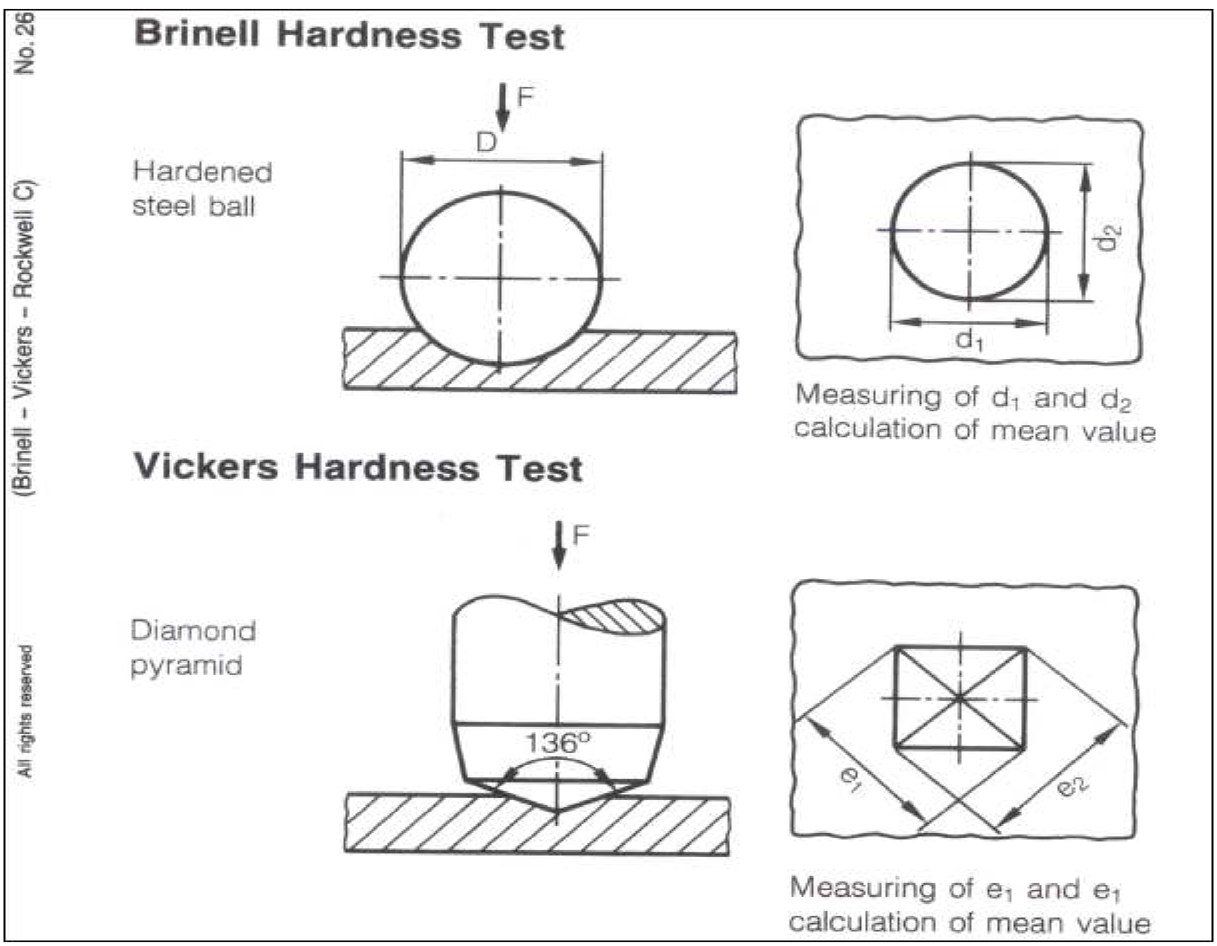




Figure 3.7. Hardness testing process

## 3.2. Joints Measurement

### 3.2.1. Inspection Tools and Measurements

Measurement and inspection of welded joint is an important step in quality control and reliability of welded constructions. External inspection allows you to detect such external defects such as undercuts, uncertified craters facing surface cracks, lack of fusion, flows, etc. Meters of welded joints and welding templates (templates welder) allow us to determine the size of joints, joint width and high, angle of bevel, depth and width of preparation, included angle, root gap, depth of root face, convexity, smoothness of transition weld to the base metal, leg length, etc.

### 3.2.2. Joints Measurement and other defects

**A. Fillet welds**

The leg length of the largest right isosceles triangle that can be inscribed within the fillet weld cross section is the size of the fillet weld. There are two types of fillet welds: concave and convex. The fillet weld type is determined by the shape of the fillet weld. Fillet weld gauges such as the ones in figure below are for specific size fillet welds and are two-sided in order to measure both concave and convex fillet welds. Be sure to use the proper side of the gauge for the fillet weld type being measured.

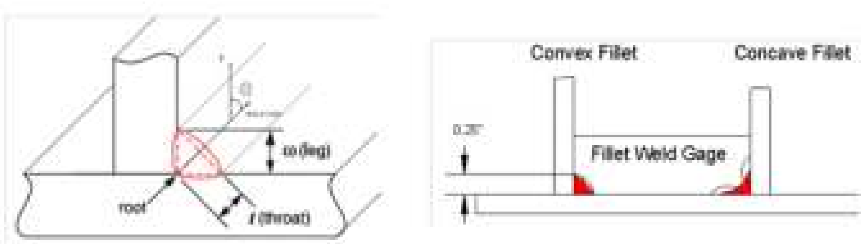



Figure 3.8. Fillet welds

Figure 3.9. Fillet gauge

Fillet welds can be measured using a gauge set as shown in Figure 3.10-3.12 below. The gauges can be used on both concave and convex fillet welds as long as the user understandsshow a fillet is measured. Whether measuring fillet welds or other weld features, the key tousing these gauges is to make sure they are sitting flat against the surface.

Figure 3.10. V-WAC gauge

Figure 3.11.Throat measurement with cam gauge

Figure 3.12.Bridge cam gauge

Note: Fillet welds are designed based on their cross-sectional area, which is calculated by the throat times the length. Drawing callouts for fillet sizes are given as the leg size. It is important for the inspector to understand that concave fillet welds cannot be measured by their leg size. Concave tools measure the throat and convert this size to the equivalent leg.

### B. Undercut

Undercut is measured from the surface of the base metal to the deepest point of the undercut. Undercut can be quickly identified by running a flashlight along the edge of weld parallel to the surface of the base metal.

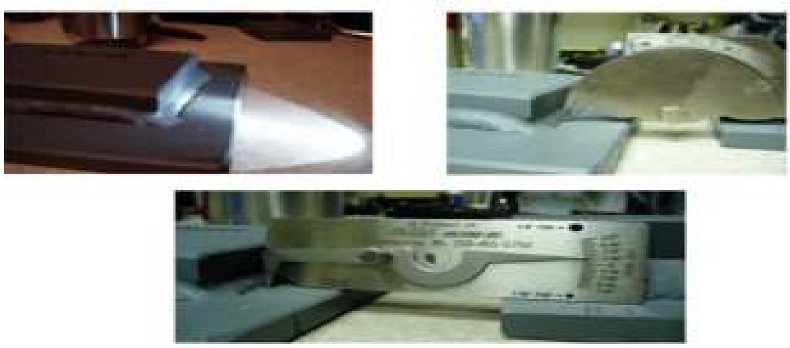


Figure 3.13. Measuring Undercut

### C. Reinforcement

Face reinforcement is measured from the top surface of the base metal to the top of the face of the weld. Root reinforcement is measured from the bottom surface of the weld to the root surface of the weld.

Figure 3.14.Measuring weld Reinforcement

Note: There are many other welding inspection tools available. Selection of these tools should be based on an evaluation of the attributes you are trying to verify. Practice with each selected tool is essential.

## 3.4. Clean and maintain welding equipment and work area

Tool housekeeping is very important, whether in the tool room, on the rack, in the yard, or on the bench all ways after completing operations. Tools require suitable fixtures with marked locations to provide an orderly arrangement. Returning tools promptly after use reduces the chance of it being misplaced or lost. Workers should regularly inspect, clean and repair all tools and take any damaged or worn tools out of service.

- Ensure sufficient time for materials to cool before handling.
- Switch off machine and fume extraction (if relevant).
- Hang up electrode holder and welding cables.

- Practice good housekeeping and ensure the area is clean and tidy.

### 3.4.1. Housekeeping in the Welding Shop Environment

Housekeeping in the welding shop environment is a key feature that all shops should possess. Without an organized shop many things we don't want to happen could occur. Cleaning up our shop area is just as important as making a good weld. Someone who takes pride in their work also takes pride in their work environment. Many shops have a lot of stuff stored in and around the shop, it's been there for years and is rarely used. Some shops have so much stuff in it you can barely move around or find anything. Other shops or well-organized and everything has a place and everything is in its place. Which one of these descriptions describes the shop or work environment you populate?

A well-organized shop saves time money and effort in many different ways. First, if the materials for fabrication are stored properly, it easy and quick to locate the proper material that we need to fabricate any project that we might want to build. Also if the shops material is well-organized it makes it very easy for the shop supervisor, project manager or plant manager to inventory the materials and see what's present. Understanding what is there what is available and in what sizes and thicknesses will help eliminate duplicate material orders for something we already have in stock. Also when it comes time to build the project the layout person, fitter or welder can easily and rapidly find the material required by the blueprint or technical drawing. Since labor is the most expensive component of fabricating most projects this savings of labor could amount to a large savings for the shop, possibly hundreds or thousands of dollars.

Since safety is a key component of everything we do in the welding world, housekeeping is just as critical to safety as wearing safety glasses, the proper clothing, boots, face and eye protection. Having our tools, equipment, hoses, cords, welding leads and our material well-organized in and around where we're going to do our fabrication, eliminates many of the tripping hazards and other safety issues associated with our welding shop environment. Having an injured shop employee does not help meet deadlines or get work done, its only a setback to the company. Just one injured employee can result in thousands of dollars of cost to the shop or fabricator. If we would just keep our area clean and organized we could use those thousands of dollars of cost on new equipment, more materials, employee benefits or other things that our shop really needs. Just as important as having a well-organized shop at the beginning of the project, cleaning up our mess, returning everything to its proper location and returning the materials to where they belong at the end of the project is just as important in the preparation for the next project is as finishing up the present project.

The best way to organize our welding shop is to think about the flow of work through it and place the materials, machines and equipment in a logical place and manner that meets your requirements and keeps the operation efficient. Look around your shop open up your eyes and think about what you could do to improve your area. In all our shops we can easily find something that we could do better and if we focus on those single items and continue to improve bit by bit, item by item, over the long haul we will see the benefits of having a well-organized shop, improved safety and cost savings.

### 3.4.2. Maintenance of equipment

You must ensure that any equipment used in welding is adequately maintained. Electrical equipment such as power sources, generators and welding machines and devices like ventilation systems and equipment must be properly installed, maintained, repaired and tested. Equipment used with compressed gases, including regulators, must be properly maintained to prevent hazards such as gas leaks. Persons with management or control of workplaces must ensure that gas cylinders are regularly inspected by a competent person. They should frequently check whether cylinders and regulators are visibly damaged or corroded, and whether they are within test date. Gas pipes, hoses and tubing can easily become damaged over time so these should also be inspected regularly. PPE must be maintained to be in good working order and kept clean and hygienic. Some types of personal protective equipment have a limited life span and need to be replaced periodically, while other types of personal protective equipment may become damaged or ineffective if stored incorrectly. For example, some respirators and filters can absorb toxins and contaminants in the air when stored between uses. PPE should be stored in a clean environment to avoid contamination or damage or according to instructions provided by the manufacturer.

### 3.4.3. Clean up work area

After operations, the shop should be cleaned. Electrode stubs should be disposed of, any scrap metal should be placed in the scrap metal container, the floor should be swept, and any water or other liquids spilled should be wiped up. Keeping the area around your work neat is as important as maintain your equipment.

- Clean your work area after completing your task (activity)
- Clean all tool , equipment and machines after practical work
- Cleaning your work area, Not only help to protect yourself from accident, but also much easier for you to work efficiently.
- Turn off all machines and power supply after work
- Keep all your equipment, cable, hoses etc out of any traffic routes. Such as
    - ✓ Door
    - ✓ Hallways
    - ✓ Ladder

- Inspect your equipment and found to be ok, but all your caution won't matter, when for example , a co-worker trip over your cable, causing you, or other people around you , to be injured by shock, hot metal , or from falling , there for your work area should always neat.
- Clean, collect and return all hand tool and safety equipment to supply room or to its original position.
- Dispose waste are Waste can be classified: Decomposed, Reuse, Waste.
- All class of wastes are selected , classified and disposed safely

Clean check and Maintain tools and Equipment: Should handle carefully while using, Check the functionality of tools and equipment before start welding and after complete welding, if there is damaged tool and equipment, you should maintain if you are skilled, report to responsible person location. Tools and equipment include

- Hand and power tools
- Measuring equipment

- Arc welding equipment
- Safety device etc.

All tools and equipment should be

- Cleaned
- Chided
- Maintained
- Stored at their proper location

## 3.5. Post-welding treatments

Heat Treatment of Base Materials and Welded Joints

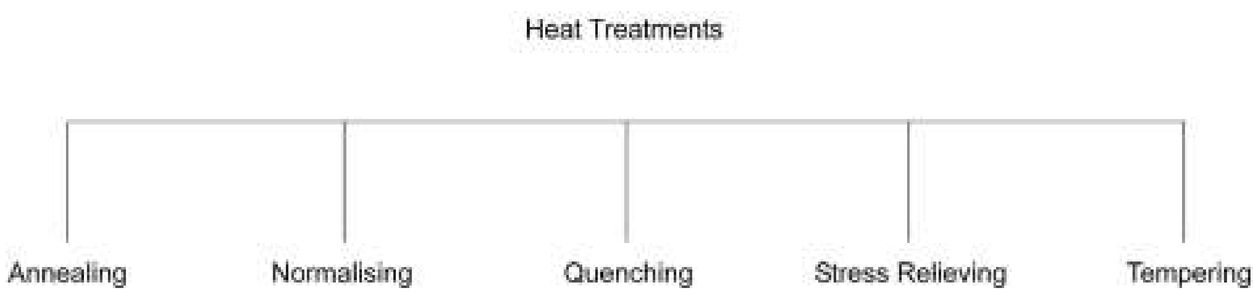



Figure 3.15. Division of various heat treatments

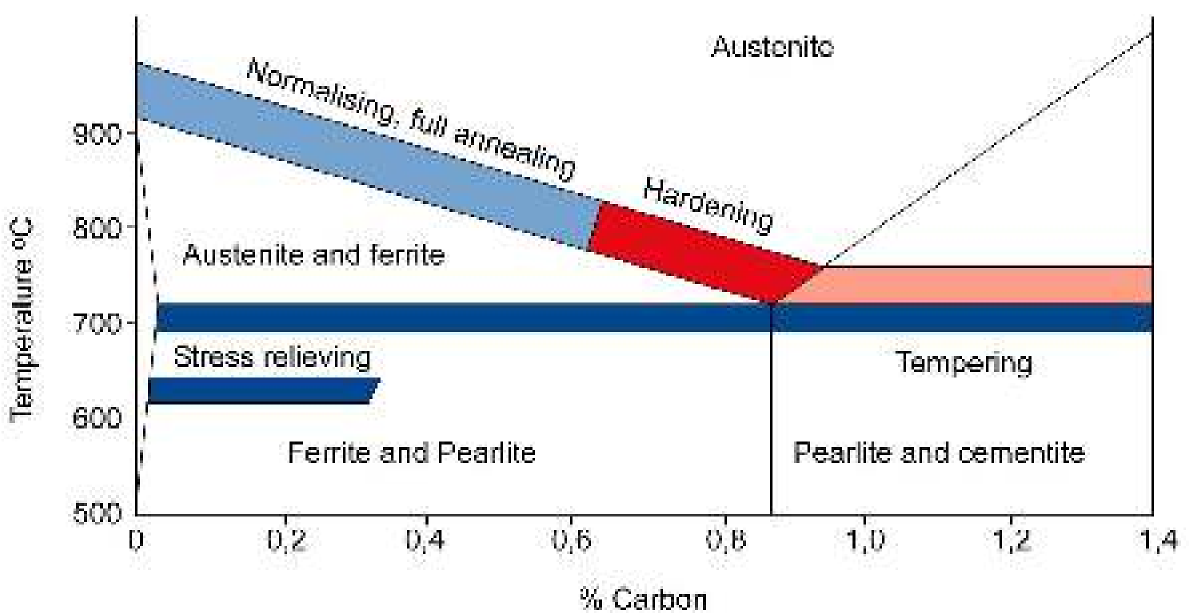


Figure 3.16.heat treatment phase diagram

There are commonly four types of heat treatment process is the manufacturing process:

- Annealing

This consists of raising the temperature of the steel to about 30°C above the upper critical temperature range. This temperature is held for one hour per 25mm thickness of material and then slowly cooled in the furnace. This results in a soft ductile structure.

- Quenching

This is accomplished by heating the steel to about 30°C above the upper critical temperature range and held at temperature for one hour per 25mm thickness, and then cooling quickly in oil, water or brine to exceed the critical cooling rate of the material. This results in a hard brittle martensitic structure.

- Stress Relieving

For this study the Uniform heating of a structure to a suitable temperature below the critical range of the base metal ± 600 to 650°C. Hold at temperature for one hour per 25mm thickness of material, followed by uniform cooling. No changes in the micro structure will occur. The objective is to relieve the stresses in a material.

- Tempering

In tempering Heat up to a temperature below the A1 line and hold for a specific time, cool in still air or oil. Hard brittle martensitic becomes tough due to carbide precipitation. Time and temperature depend upon the degree of softening required.

- Effect of tempering on properties
- Reduces UTS
- Reduces Yield strength

- Improves elongation
- Improves reduction of area
- Improves ductility

### 3.5.1. Reasons for Post-weld Heat Treatments

- Relieve stresses
- Improve toughness
- Increase strength
- Improve corrosion resistance
- Remove cold work

### 3.5.2. Welding Process and Its Effects

The welding process applied to metals joins two components together by fusion. The surfaces to be joined are raised locally to melting point by a source of heat provided by a variety of welding methods based on electric arc, electric resistance, and flame. The process energy creates a localized molten pool into which the consumable is fed, fusing with the component surfaces and/or previously deposited weld metal. As the molten pool is moved along the joint axis, the components are heated, non-uniformly and subsequently cooled, also non-uniformly. Neighboring elements of material try to expand and contract by differing amounts in accordance with the sequence of the localized thermal cycle.

## Self-check: Three

**Instruction Three: choose the correct answer**

1. Which one of the following is not the causes of undercut?
   A. Your electrode is too large for the base metal
   B. Your arc length is too long
   C. Your speed of travel too fast
   D. You have amperage set too high
2. __________is the welding defect in which the base metal is burned away at toes of weld
   A. Under cutting
   B. Porosity
   C. Cracks
   D. Incomplete fusion
3. In which type of crack happens well after a weld is completed and the metal has cooled off.
   A. Hot crack
   B. Cold crack
   C Crater cracks.
   D. All
4. From the following one is destructive testing method
   A. Mechanical tests
   B. Visual examination
   C. X-ray fluorescence
   D. Eddy current

5. Which one of the following is section of welding record sheet
   A. Test information C. Weld information
   B. Material information D. Header E. All
6. __________nondestructive testing method is based on principles of magnetism
   A. Eddy current testing C. Ultrasonic examination
   B. X-ray fluorescence D. Visual examination

**Instruction two: Say true or false**

1. Cast number is unique number given to every welder in a company.
2. Machine model number is the type of model of welding machine used to complete the welding.
3. A weld record sheet is used to track the critical information for each specific weld completed in a system.

## Operation sheet:1

**Operation title:**Inspecting and maintaining Weld records

**Purpose: Inspecting and maintaining Weld records**

**Conditions or situations for the operations:**

**Equipment tools and materials:** destructive test, non-destructive

**Procedure:**

Step1. Safety (clean work area &wear PPE)

Step2. Prepare tools and equipment.

Step3. Select inspection method.

Step4. Check the weld

Step5. If the weld does not correct.

Step6. Re-weld the joint

Step9. Record the document.

Step10. Clean the work area.

Note: Save the welded plate for testing later.

**Precaution**: The welder must have face and eye protection when chipping welds. Open the window in the hood but keep the hood down when chipping or brushing welds. The metal is hot. Handle it with pliers

**Quality criteria:** identify the quality weld product

## Operation sheet:2

**Operation title:** Safety (OHS) procedures

**Purpose: understand the safety (OHS) procedures**

**Conditions and situations: safe working area, availability of the materials**

**Equipment tools and materials:** safety materials, equipment

**Procedure:**

Step 1. Remove any flammable matter from the area.

Step 2. Ensure that the area has adequate "ventilation" (fresh air).

Step 3. Check that exhaust fans are running

Step 4. Remove all obstacles or debris

Step 5. Wear the appropriate personal protective equipment.

Note: Save the welded plate for testing later.

**Precaution**: The welder must have face and eye protection when chipping welds. Open the window in the hood but keep the hood down when chipping or brushing welds. The metal is hot. Handle it with pliers

**Quality criteria:** identify the quality weld product

## Lap TestPractical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 4 hour.

Task 1. Inspecting, maintaining, and recording Weld joint.

Task 2. Clean work area.

Task 3. Clean work area free from accident