Basic Metal Works

Level-I

Learning Guide-44

Unit of Competence:	**Perform routine arc welding**
Module Title:	**Performing routine arc welding**
LG Code:	**INDBMW1M13 LO1-LG-44**
TTLM Code:	**INDBMW1M13 TTLM 1019v1**

LO 1: Plan and prepare welding work

Instruction Sheet	Learning Guide #44

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

- Identifying Welding requirements
- Selecting Materials and appropriate welding equipment

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

- Identify Welding requirements
- Select Materials and appropriate welding equipment

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information "Sheet 1, Sheet 2, Sheet 3 and Sheet 4".
4. Accomplish the "Self-check 1, Self-check t 2, Self-check 3 and Self-check 4" **in page -6, 9, 12 and 14** respectively.
5. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1, Operation Sheet 2 and Operation Sheet 3 " **in page -15.**
6. Do the "LAP test" **in page – 16** (if you are ready).

Information Sheet-1	Identifying Welding requirements

1.1. Introduction to 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 welding is to be discussed.

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.

Weldability – the ability of a material to be welded under prescribed conditions and to perform as 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

1.3. 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-oxidising 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.

1.4. 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.

1.5. Electricity and welding

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.

1.6. 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.

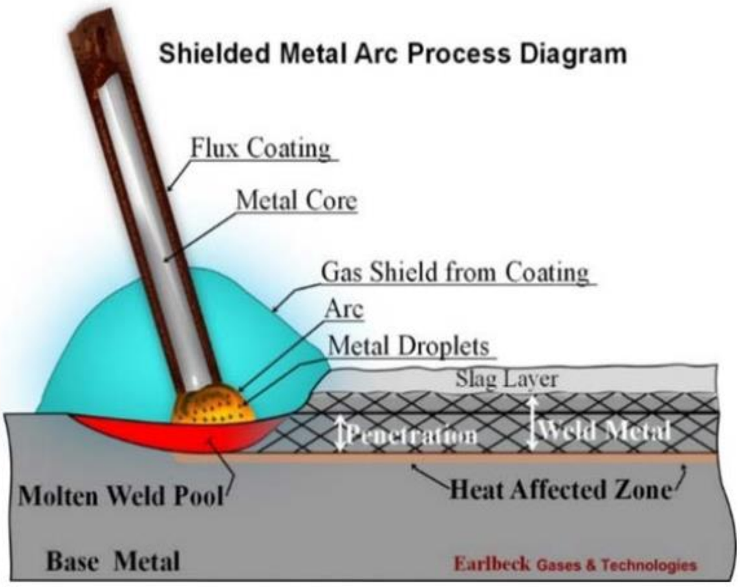


Figure:1.1 Manual metal arc welding diagram

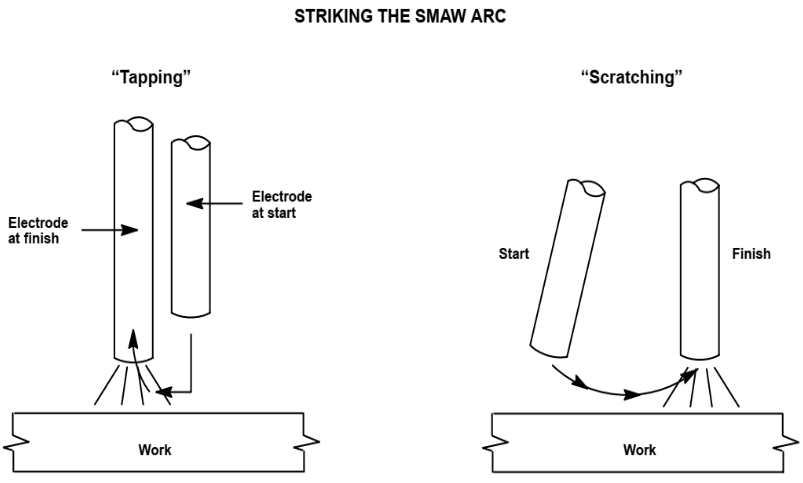


Figure : 1.2 Illustration of Tagging and scratching

Self-Check -1	Written Test

Direction1: Multiple choice

Instruction1- Choose and write the letter of the correct answer on the space provided

1. The great of an electric arc which is used for melting to joining metallic pieces in welding is caused by

A. Resistance of air in between pieces
B. Electrical conductivity of the air gap between the pieces
C. Electrical conductivity of metallic pieces
D. Ignition from lighters

2. Which one of the following is not the function of electrode?

A. Conducts electricity
B. Used as filler
C. Completes electrical circuit of the welding equipment
D. Used as gas shielding agent

3. Which one is 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.

A. Spatter C. Grease
B. Flux D. Molten metal

4. Which one of the following gases negatively affect the quality of welds?

A. Helium D. Nitrogen
B. Oxygen E. B and D
C. Argon

Note: **Satisfactory rating - 3 and 5 points** **Unsatisfactory - below 3 and 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Information Sheet- 2	Selecting Materials and appropriate welding equipment

2.1. Materials welded by MMAW/SMAW

SMAW dominates other welding processes in the maintenance and repair industry in particular. Although flux-cored arc welding is growing in popularity, SMAW continues to be used extensively in the construction of steel structures and in industrial fabrication. The process is used primarily to weld 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.

2.2. Arc Welding Equipment

Arc welding equipment, setup and related tools and accessories are shown in Figure below. However some common tools of arc welding are shown separately through Figure. Few of the important components of arc welding setup are described as under.

1. **Arc welding power source**

Both direct current (DC) and alternating current (AC) are used for electric arc welding, each having its particular applications. DC welding supply is usually obtained from generators driven by electric motor or if no electricity is available by internal combustion engines. For AC welding supply, transformers are predominantly used for almost all Arc-welding where mains electricity supply is available. They have to step down the usual supply voltage (200-400 volts) to the normal open circuit welding voltage (50-90 volts). The following factors influence the selection of a power source:

- Type of electrodes to be used and metals to be welded
- Available power source (AC or DC)
- Required output
- Duty cycle
- Efficiency
- Initial costs and running costs
- Available floor space
- Versatility of equipment

2. **Welding cables**

Welding cables are required for conduction of current from the power source through the electrode holder, the arc, the work piece and back to the welding power source. These are insulated copper or aluminum cables.

3. **Electrode holder**

Electrode holder is used for holding the electrode manually and conducting current to it. These are usually matched to the size of the lead, which in turn matched to the amperage output of the arc welder. Electrode holders are available in sizes that range from 150 to 500 Amps.

4. **Welding Electrodes**

An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. An arc is set up between electrode and work piece. Welding electrodes are classified into following types-

(i) Consumable Electrodes

- Bare Electrodes
- Coated Electrodes

(ii) Non-consumable Electrodes

- Carbon or Graphite Electrodes
- Tungsten Electrodes

Consumable electrode is made of different metals and their alloys. The end of this electrode starts melting when arc is struck between the electrode and work piece. Thus consumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloy wire without any flux coating on them. Coated electrodes have flux coating which starts melting as soon as an electric arc is struck. This coating on melting performs many functions like prevention of joint from atmospheric contamination, arc stabilizers etc.

Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc. These electrodes do not melt away during welding. But practically, the electrode length goes on decreasing with the passage of time, because of oxidation and vaporization of the electrode material during welding. The materials of non-consumable electrodes are usually copper coated carbon or graphite, pure tungsten, thoriated or zirconiated tungsten.

Note: In this level we are going to use consumable electrodes usually coated.

5. **Hand Screen**

Hand screen used for protection of eyes and supervision of weld bead.

6. **Chipping hammer**

Chipping Hammer is used to remove the slag by striking.

7. **Wire brush**

Wire brush is used to clean the surface to be weld.

8. **Protective clothing**

Operator wears the protective clothing such as apron to keep away the exposure of direct heat to the body.

The following figures are used to describe the welding equipments and their configuration

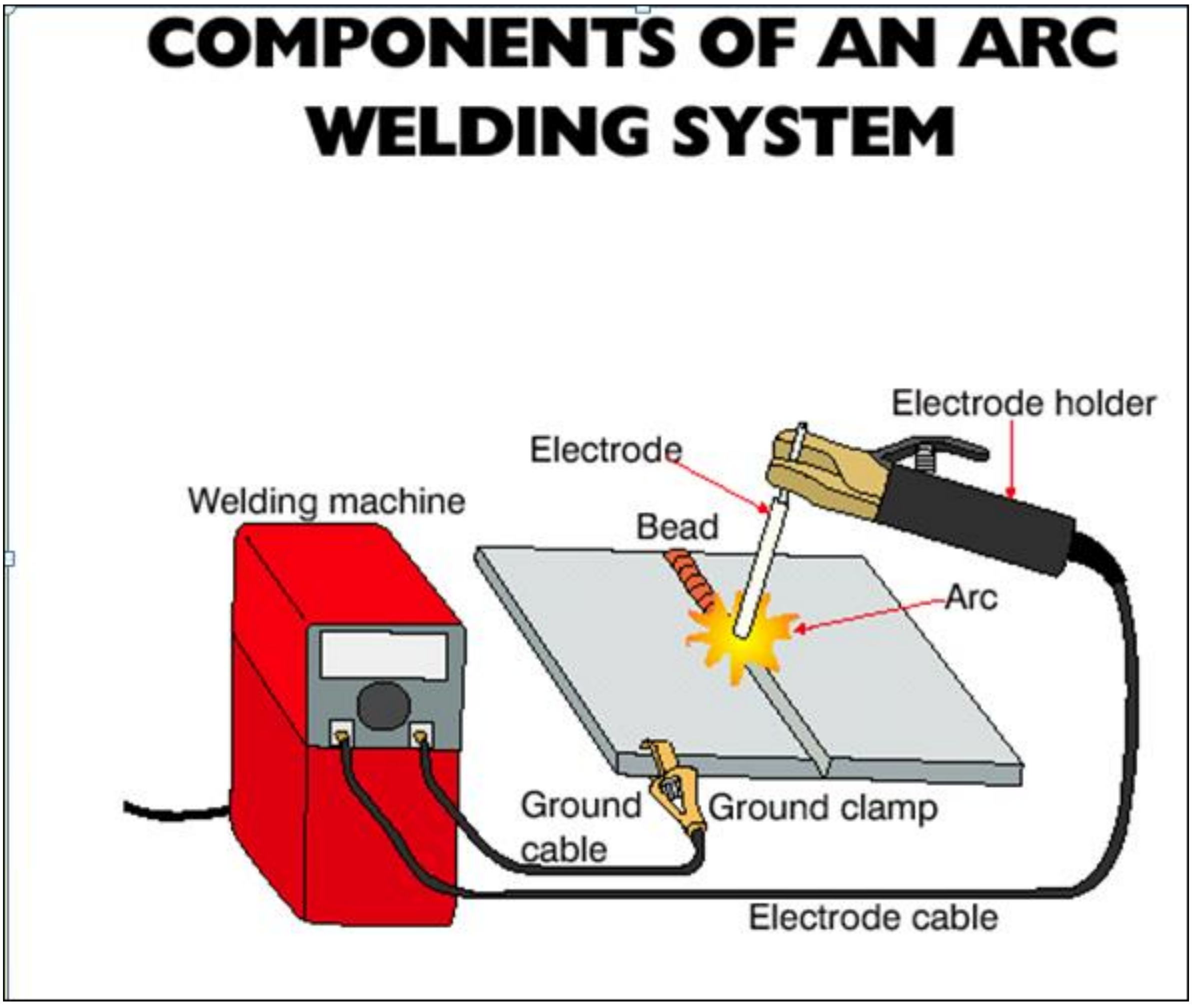


Figure 2.1: components of an arc welding machine

Figure 2.3: welding machine

2.3. Other tools

The following tools are commonly used in metal welding shops:

- **Steel rule**
- **Try square**
- **Scriber**
- **Hacksaw**
- **Bench vice**
- **Flat file**
- **Face shield**
- **Tongs**
- **Wire-brush**
- **Chipping hammer**
- **Portable grinder**

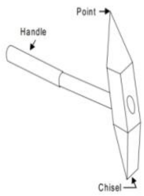


Fig. Chipping Hammer

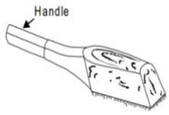


Fig. Wire Brush

Fig. Marking Knife

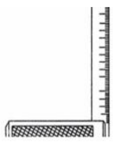


Fig. Try Square

Self-Check -2	Written Test

Direction1: Short answer items

Instruction1- Briefly answer the following questions

1. Mention materials that can be welded by MMA welding.
2. List the two types of power sources
3. List at least 5 components of a welding equipment.
4. Write the factors that can affect selection of power source for welding project?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Basic Metal Works

Level-I

Learning Guide-45

Unit of Competence:	**Perform routine arc welding**
Module Title:	**Performing routine arc welding**
LG Code:	**INDBMW1M13 LO2-LG-45**
TTLM Code:	**INDBMW1M13 TTLM 1019v1**

LO 2: Perform routine welding

Instruction Sheet	Learning Guide #45

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

- Following and applying OHS measures
- Setting up welding current
  - Weld characteristics
  - Equipment set-up and settings
  - MMAW processes and properties
- Selecting electrodes
- Preparing and cleaning materials
- Welding materials
- Cleaning Welding seams

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

- Follow and apply OHS measures
- Set up welding current
- Select electrodes
- Prepare and clean materials
- Weld materials
- Cleaning Welding seams

Learning Instructions:

7. Read the specific objectives of this Learning Guide.
8. Follow the instructions described below 3 to 6.
9. Read the information written in the information "Sheet 1, Sheet 2, Sheet 3 and Sheet 4".
10. Accomplish the "Self-check 1, Self-check t 2, Self-check 3 and Self-check 4" **in page -6, 9, 12 and 14** respectively.
11. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1, Operation Sheet 2 and Operation Sheet 3 " **in page -15.**
12. Do the "LAP test" **in page – 16** (if you are ready).

Information Sheet-1	Following and applying OHS measures

1.7. 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.

1.8. 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:
5. Gloves protect the hands of a welder.
6. Leather or asbestos apron is very useful to protect welder’s clothes and his trunk and thighs while seated he is doing welding.
7. For overhead welding, some form of protection for the head is required

8. Leather skull cap or peaked cap will do the needful.
9. Leather jackets and 1ather leggings are also available as clothes for body protection.
10. Welding equipment shall be inspected periodically and maintained in safe working order at all times.
11. Arc welding machines should be of suitable quality.
12. All parts of welding set shall be suitably enclosed and protected to meet the usual service conditions.

1.9. Personal protective equipment (PPE)

Arc welding, like most welding processes, requires operators to protect themselves from the radiated heat and rays associated with the process. Perhaps the most efficient way of doing this is by the wearing of protective clothing.

The use of all protective clothing is dictated by the nature of the work and the comfort of the operator. Ideally, clothing for the operator should consist of:

- long-sleeved cotton shirt
- sleeves rolled down and buttoned
- strong trousers without cuffs
- strong leather shoes or work boots
- aprons
- gloves
- spats (leather)
- caps
- leather capes or jackets.

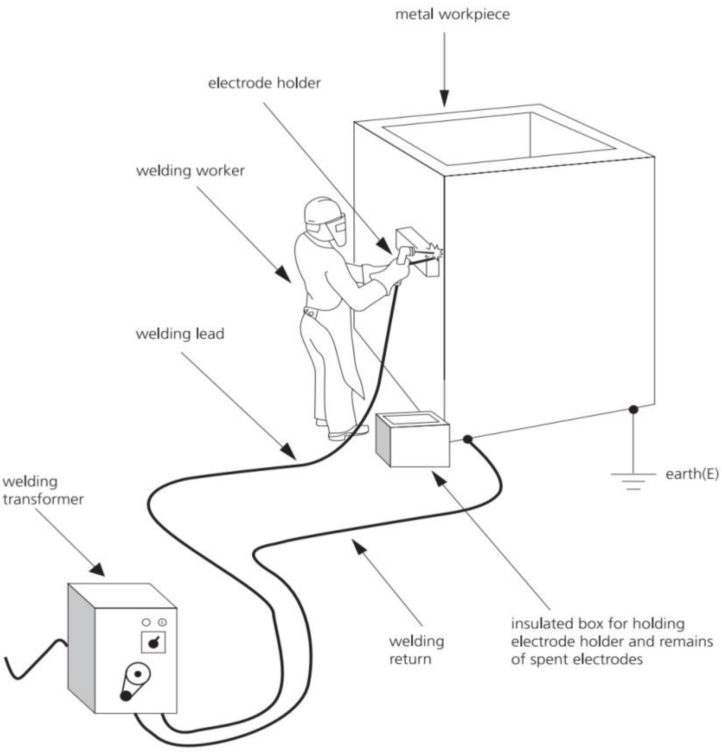


Figure 1.1: A general working arrangement of manual electric arc welding operation

1.10. 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:

- Fires caused by sparks or globules of molten metal generated during the welding work igniting the combustible material in the vicinity of the work;
- Fires caused by the hot welding electrode that igniting the combustible material in the vicinity of the work;
- Fires and explosions caused by the ignition of critical mixtures of gases, volatile flammable liquids or combustible dusts with air;
- Fires and explosions arising from the ignition of the combustible/ flammable residue in the work piece; and
- 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.

- **Gases**

A number of toxic gases such as carbon monoxide, nitrogen oxides, ozone and various decomposition products of halogenated hydrocarbons are present or produced during welding.

i. Asphyxiation due to lack of oxygen or accumulation of shielding gases such as argon, carbon dioxide, helium and nitrogen in confined work environment;
ii. Hazardous substances such as phenol, formaldehyde, acrolein, isocyanates and hydrogen cyanide from thermal decomposition of resins used in primers and paints on welding surfaces;
iii. The toxic gas phosgene and other irritant gases may be formed when welding is carried out in the presence of chlorinated solvent vapours (for example, trichloroethylene, trichloroethane and perchloroethylene) escaping from a nearby degreasing tank or the solvent left behind after degreasing.

E. Other related hazards

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

- Hazards related to the access to and working at high levels such as falling from height and the loss of stability of structures used to access high 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.

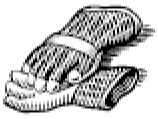
Table 1.1   Potential health & safety hazards signs

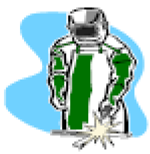
HAZARD		TO PROTECT YOURSELF
PINCH POINTS **There are gears and exposed moving parts on machinery.**		Use LOCK-OUT procedures when performing maintenance or conducting any work within 12" of an exposed pinch point. NEVER put your hands or feet near an exposed pinch point or gears!
ELECTRICAL HAZARD		Ensure all electrical equipment and machines have plugs and wires that are in good condition.
EXPLOSIVE		Make sure cylinders are stored and handled correctly. Proper grounding must be used.
HIGH SOUND LEVELS **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 • drop • keep near heat
FIRE 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 Falling objects		The appropriate ASTM or CSA approved footwear must be worn when job hazard analysis shows it is needed.

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.

Self-Check -1	Written Test

Directions: Short answer items

Instruction: Briefly answer the following questions.

1. Write at least 10 safety recommendations for welders.
2. Mention at least 4 hazards that can be caused improper handling of welding operation
3. What do we mean by **PPE**?
4. What are the major causes for the noise hazard in metallic welding shop?

***Note:* Satisfactory rating - 3 and 5 points** **Unsatisfactory - below 3 and 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _________

Information Sheet- 2	Setting up welding current

2.1. Weld characteristics

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.

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 Welding slot forms

Joining methods in welding design can be divided into four groups; such as butt, inner corner, outer corner and overlap. In welded parts, welding slot must be prepared to have better performance in joined area. The types of welding slots are determined in the related standards. In Europe, EN ISO 9692-1:2003 international welding standard is valid in this subject and the types of welding slots are determined in detailed there.

2.1.3 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 used, 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 (Black and Kohser, 2008). The electrode material in welding is desired to be high strength, ductile and tough (Oguz, 1993). 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 1 depending on work piece thickness.

2.1.4 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 (Yasar et al., 2010). 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: Determination of dimensions in welding slot forms.

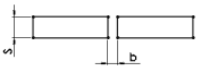
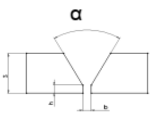
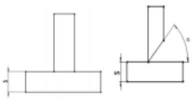
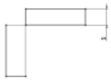
Slot form	Schematic parade	α	b	Explanation
Plain weld		0°	0	
Butt weld		0°	If s ≤ 3, b = 0,5 mm If 3 < s ≤ 8, b = 2 mm If 8 < s ≤ 20, b = 3 mm If s > 20, b = 4 mm	If s>8 mm, butt weld is not recommended, v weld slot is suggested.
V weld		60°	If s ≤ 8, b = 0 mm If s > 8, b = 2 mm	If s ≥ 8, h = 3 mm (h = base height) If s < 8, v weld slot is not suggested, butt weld slot is recommended.
Inner corner		0° 60°	If s ≤ 8, b = 0 mm If s > 8, b = 0 mm	
Outer corner		0°	0	
Overlap		0°	0	

Table 2.2: Electrode core diameters suggested by program according to work piece thickness(s)

Work piece thickness (s)	Electrode core diameter (d)	Unit
S ≤ 3	2.5	mm
3 < S ≤ 20	3.25	mm
S > 20	4.00	mm

Table 2.3: 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 ≤ 3	4.50	d × 40 ampere
S > 3 ≤ 8	4.00	d×40 ampere
S > 8	3.50	d × 40 ampere

Table 2. 4 : 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

2.1.5 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 3 according to the thickness of work piece (s), welding current (I) and diameter of electrode (d) (Durgutlu, 1997; Erturk, 1994).

2.1.6 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, short arc 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 .

2.1.7 Electrode advance angle

The molten metal can be transferred by arc along the welding process and the welder should orientate the arc to form melting on joining surfaces. The angle between electrode and advance direction is generally 45 to 70°, however this value can also be changed between 45to 90°. The main principle here is the angle should prevent the flowing of slag in front of arc excluding vertical welding from top to down. The values of ideal advance angle and tolerances are given in Table 4 depending on welding position. The advance angle values are given according to advance direction. The schematic view of advance angles is illustrated in Figure below depending on welding position. Welding seam form changes in case of lowering tolerances and linear curves are extremely decreases, and burning grooves are seen in borders and penetration is reduced. Similar alteration in seam welding is obtained if tolerances are passed over, and arc blowing is realized (below 50°) and damage

in borders is formed.

2.1.8 Electrode oscillation angle and movement

The parameter of oscillation angle directly affects the surface width of weld seam. If oscillation angle rises, the width of seam increases, when it decreases seam width lowers. Width changes depending on electrode core diameter (Welding seam width = d × 2.5 tolerance 20%). The equation oscillation angle is given in Equation

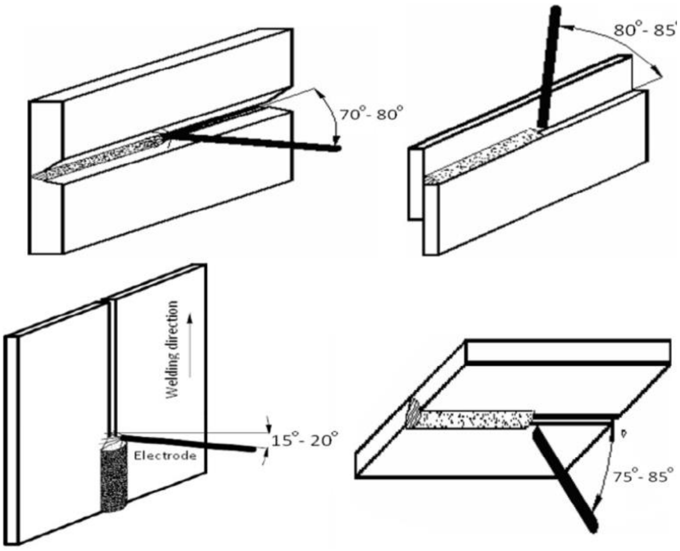


Figure 2.1 . The schematic view of advance angles depending on welding position

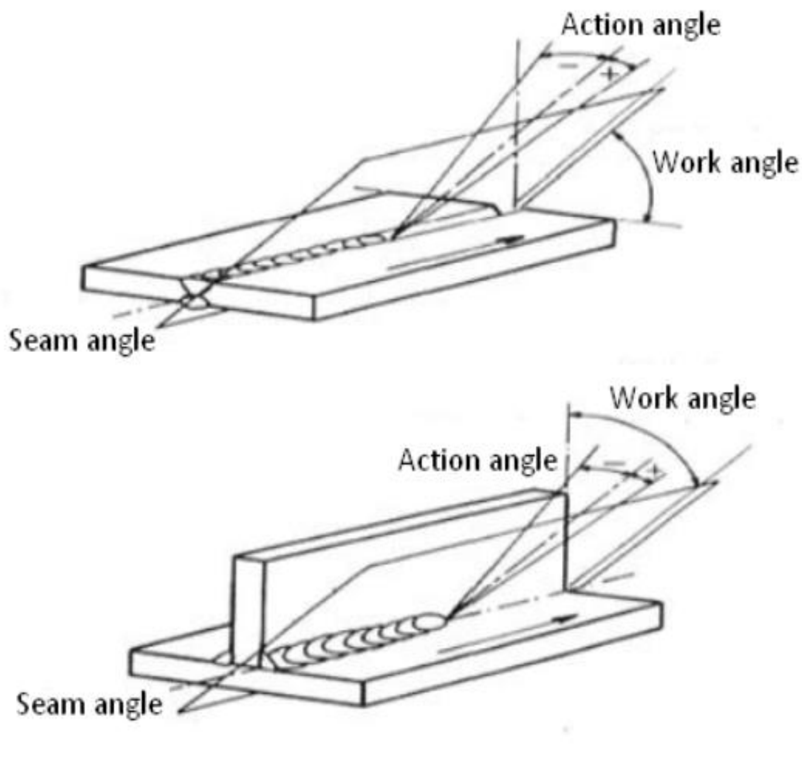


Figure 2.2: The schematic view of oscillation angle.

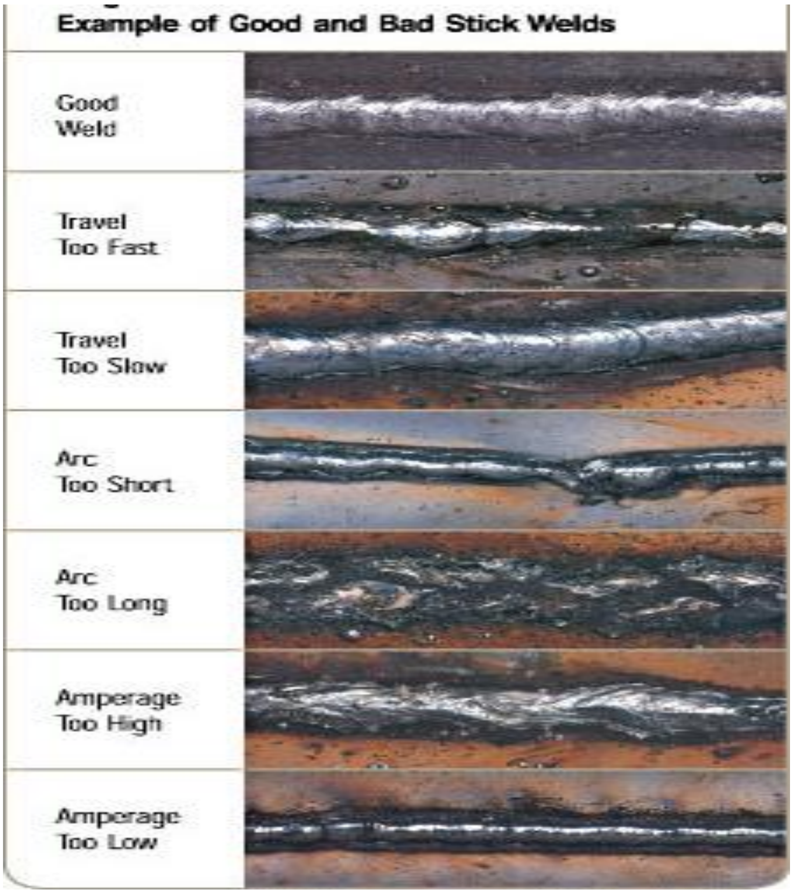


Fig 2.3: Effects of the major weld parameters: speed, current and arc length

2.2. Equipment set-up and settings

2.2.1 Setting up arc welding equipment

The work is connected to the source of electrical supply (welding set). The electrode holder, held by the operator, is ***connected*** to the same source. The following procedures are generally used to set equipment.

1. Check the working of power source for the welding machine.
2. Remember electricity is a good servant but a bad master.
3. Call an electrician for solving any electrical problems.
4. Connect the welding cables with the welding machines.
5. Ensure that the cable connections are clean, dry, tight and are attached to the proper terminals of the machine.
6. Attach tightly the earth cable with the welding table at the proper place.

7. Keep the electrode-holder at a safe place
8. If the machine is on D.C. power, connect the cables in correct polarity. Polarity means changing of +ve and -ve to the electrode is called polarity.

2.2.2 Welding current

To be suitable for welding, the current used must meet the following requirements. There must be sufficient amperage to provide the heat for fusion. The voltage must be high enough to initiate the arc, but low enough to ensure the safety of the welding operator. There must be a suitable means of current control. Mains supply is unsuitable for use as the welding current as the voltage is too high and the amperage too low. Mains supply must be 'transformed' to make it suitable for use in welding. Alternatively, the welding current can be produced from a dedicated welding generator or alternator.

The process requires sufficient electric current to melt both the electrode and a proper amount of base metal. It also requires an appropriate gap between the tip of the electrode and the base metal or the molten weld pool. These requirements are necessary to set the stage for coalescence. The sizes and types of electrodes for shielded metal arc welding define the arc voltage requirements (within the overall range of 16 to 40 V) and the amperage requirements (within the overall range of 20 to 550 A). The power source must be able to control the level of current within a reasonable range in order to respond to the complex variables of the welding process itself. Electric current may be either:

- Alternating current (AC)
- Direct current (DC)

2.2.3 Definitions of basic terms

Term	Definition
Voltage (V)	the force which makes current flow voltage is essentially electrical pressure
Current (A)	the flow of electrons and is measured in amperes
Open circuit voltage(OCV)	the voltage between welding terminals when the machine is switched on but welding is not in progress
Resistance	the hindrance of a conductor to the passage of current, ie a force which opposes the flow of electricity
Conductor	a material that permits the easy flow of electricity
Insulator	a material that will not convey an electric current

2.2.4 Selecting welding Current

It is important to consider various aspects while selecting suitable type of welding current for developing weld joints in a given situation. Some of the points need careful considerations for selection of welding current are given below.

1. Thickness of plate/sheet to be welded: DC for thin sheet to exploit better control over heat
2. Length of cable required: AC for situations where long cables are required during welding as they cause less voltage drop i.e. loading on power source
3. Ease of arc initiation and maintenance needed even with low current: DC preferred over AC
4. Arc blow: AC helps to overcome the arc blow as it is primarily observed with DC only.
5. Odd position welding: DC is preferred over AC for odd position welding (vertical and overhead) due to better control over heat input.
6. Polarity selection for controlling the melting rate, penetration and welding deposition rate: DC preferred over AC

7. AC gives the penetration and electrode melting rate somewhat in between that is offered by **DCEN&DCEP.**

DC offers the advantage of polarity selection **DCEN&DCEP**) which helps in controlling the melting rate, penetration and required welding deposition rate (Fig. 2.3). DCEP results in more heat at work piece producing high welding speed but with shallow penetration. DCEN polarity is generally used for welding of all types of steel. DCEP is commonly used for welding of non-ferrous metal besides other metal systems. AC gives the penetration and electrode melting rate somewhat in between of that is offered by DCEN&DCEP.

The welding current used for stick welding may be either alternating current or direct current depending on the electrode being used.
DIRECT CURRENT is the most common current choice for stick welding. The current flows in one direction only and has many advantages over alternating current for the stick process. These advantages include:
fewer arc outages, less spatter, easier arc starting, less sticking, and better control in out-of-position welds.

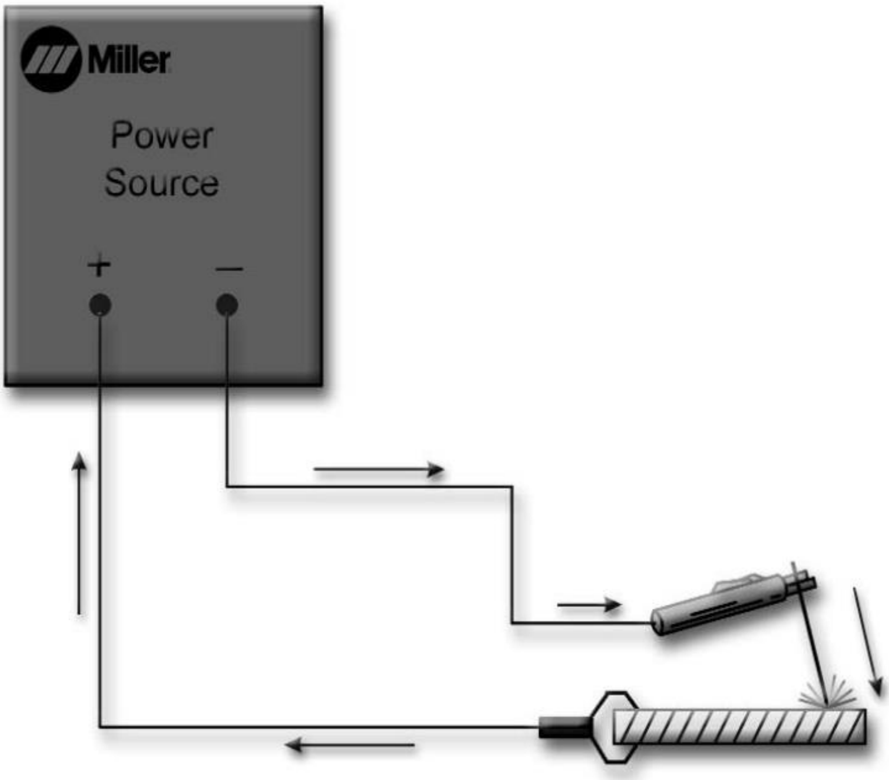


Fig 2.3: Direct Current welding circuit

The polarity of the direct current welding arc or the direction of electrical current flow is very important. When the electrode cable is connected to the power sources positive output connection and the work cable is connected to the negative output connection this is a DCEP or Reverse Polarity connection. When the electrode cable is connected to the negative and the work cable is connected to the positive this is a DCEN or Straight Polarity Connection. For SMAW, the DCEP connection is used most often. It provides for the best penetration and bead profile. For this reason most electrodes are made to weld with DCEP

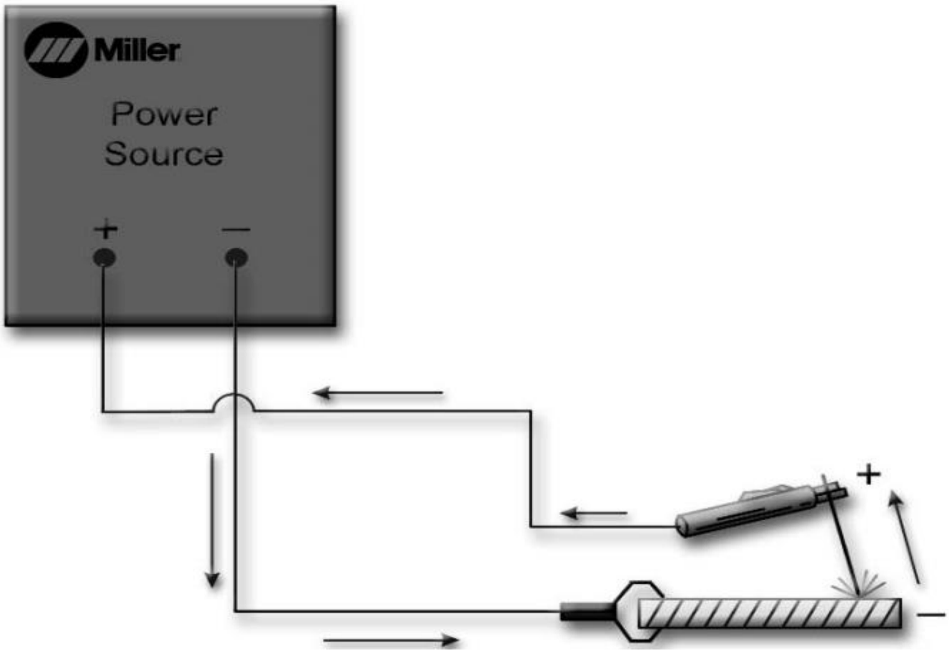


Figure 2.4; Direct current electro positive connection

Using a DCEN connection for SMAW will result in a narrow bead with little penetration. This connection works well when welding on sheet metal or for hard surfacing electrodes.

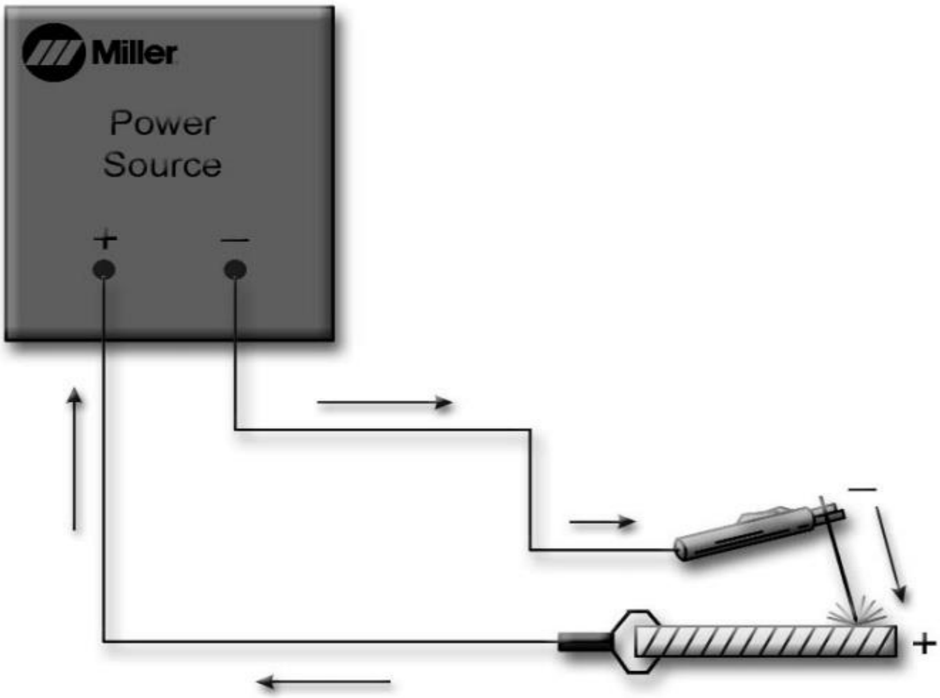


Figure 2.5: Direct Current Electrode Negative Connection

ALTERNATING CURRENT (AC) is an electrical current that has both a positive and a negative half-cycle value (polarities) alternately. Current flows in a specific direction for one half-cycle, stops at the "zero" line, then reverses direction of flow the next half-cycle at regular intervals. The AC sine wave represents the current flow as it builds in amount and time in the positive direction and then decreases in value and finally reaches zero. The current then reverses direction and polarity reaching a maximum negative value before rising to the zero value. This alternating repeats as long as the current is flowing.

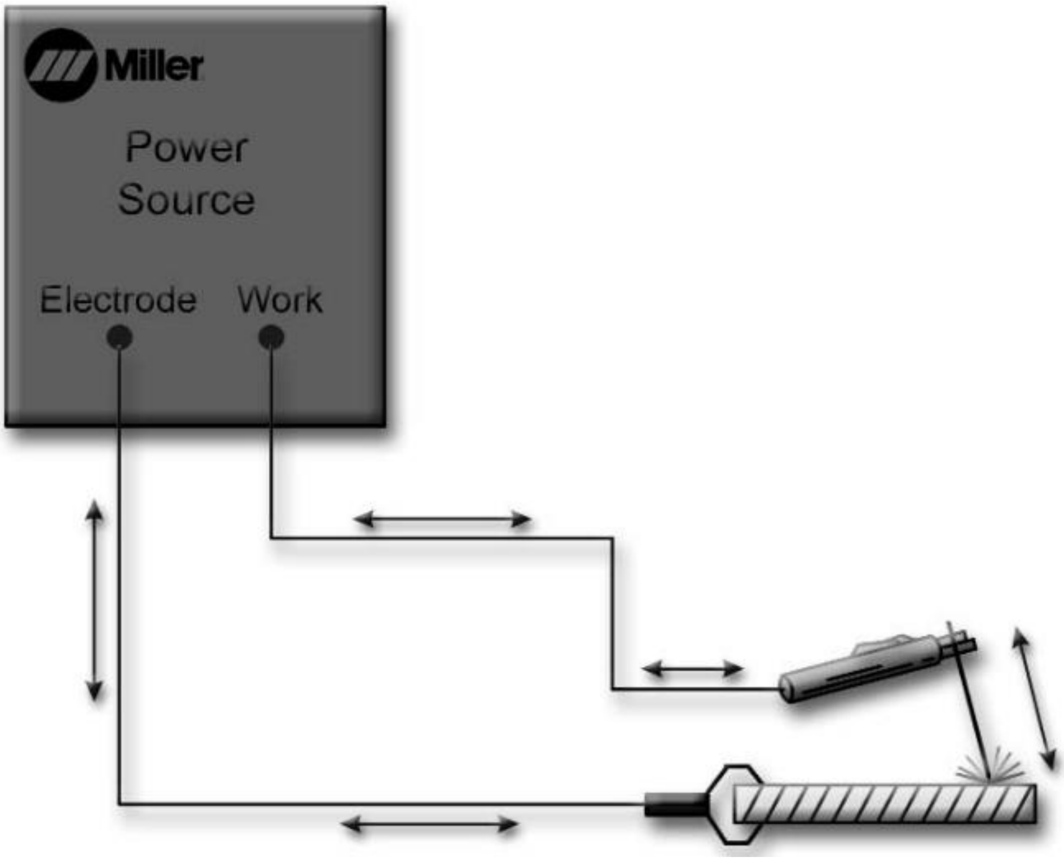


Figure 2.6: Alternating Current Welding Circuit

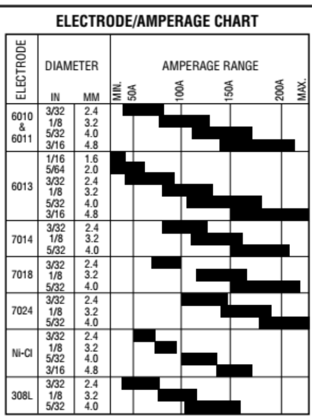
An AC only SMAW power source is the most economical type of welding power source available. Because of the alternating characteristic of the current, however, the resulting arc and weld will tend to have more spatter, less penetration, and more arc outages than a weld made with direct current. One situation when alternating current would work better than direct current is if the operator is encountering magnetic arc blow. **MAGNETIC ARC BLOW or ARC BLOW** is an arc magnetism phenomena that causes the arc to fluctuate or move in various and erratic directions. Magnets have a north pole (+) and a south pole (-) and it is known that like charges repel and unlike charges attract. This magnetic attraction and repelling occur in some types of direct current welding operations. It is due to the principle that as an electric current moves through a conductor, a magnetic field is created. The strength of this magnetic field will vary with the amount of welding current, position of the electrode on the joint, and size of pieces being welded. This varying arc condition obviously tends toward instability of the arc. It may be responsible for lack of fusion, porosity and an unevenly welded joint. It is normally not experienced in alternating current arc welding.

2.2.5 Setting Current

The amount of current needed to weld a part depends on several factors, including: type and position of joint, metal type and thickness, electrode type and diameter. With experience, the operator is able to determine how much current is need for the job at hand. For experienced operators there are several ways to establish a starting point for setting current.

One method for determining the amount of amperage needed is to take the diameter of the electrode, which is expressed as a fraction, and convert it to a decimal. That number becomes the starting point for amperage. For example, the decimal equivalent of 1/8” is .125”. The amperage starting point for amperage on a 1/8” electrode would be 125 amps. Because each type of electrode has a different amperage range this method is not very accurate, however, it is a simple way to establish a starting point.

On some power sources there will be a chart that shows the amperage ranges for different diameters and types of electrodes. The illustration below shows one of these charts. This chart may also provide the operator with other information on the electrode such as the type of current the electrode operates on, the positions it can be used in, and the polartiy needed for DC operation.



ELECTRODE	DC*	AC	POSITION	PENETRATION	USAGE
6010	EP	—	ALL	DEEP	MIN. PREP, ROUGH, HIGH SPATTER
6011	EP	✓	ALL	DEEP	
6013	EP, EN	✓	ALL	LOW	GENERAL
7014	EP, EN	✓	ALL	MED.	SMOOTH, EASY, FAST
7018	EP	✓	ALL	LOW	LOW HYDROGEN, STRONG
7024	EP, EN	✓	FLAT HORIZ. FILLET	LOW	SMOOTH, EASY, FASTER
Ni-Cl	EP	✓	ALL	LOW	CAST IRON
308L	EP	✓	ALL	LOW	STAINLESS

*EP = ELECTRODE POSITIVE (REVERSE POLARITY)
EN = ELECTRODE NEGATIVE (STRAIGHT POLARITY)

Electrode/Amperage Selector Chart

Table 2.4

Arc Force Control & Hot Start

Many of Miller Electric's power sources that have constant current output are equipped with a feature called Arc Force, Dig or Arc Control, and Hot Start. These features can be a big advantage to the welder who knows what these controls are designed to do.

Arc Force Control-Additional Amperage In a Low Voltage Situation

To understand arc control, you must understand the relationship between arc length and voltage. A basic fact for electric arc welding processes is this: As arc length increases, voltage goes up; and as arc length decreases, voltage goes down. When a welder is using a constant current machine, he or she is controlling load voltage by controlling the arc length. However, as arc length decreases and voltage goes down - such as during arc initiation when the arc length is zero, or during open root welds - there is a tendency for the electrode to stick

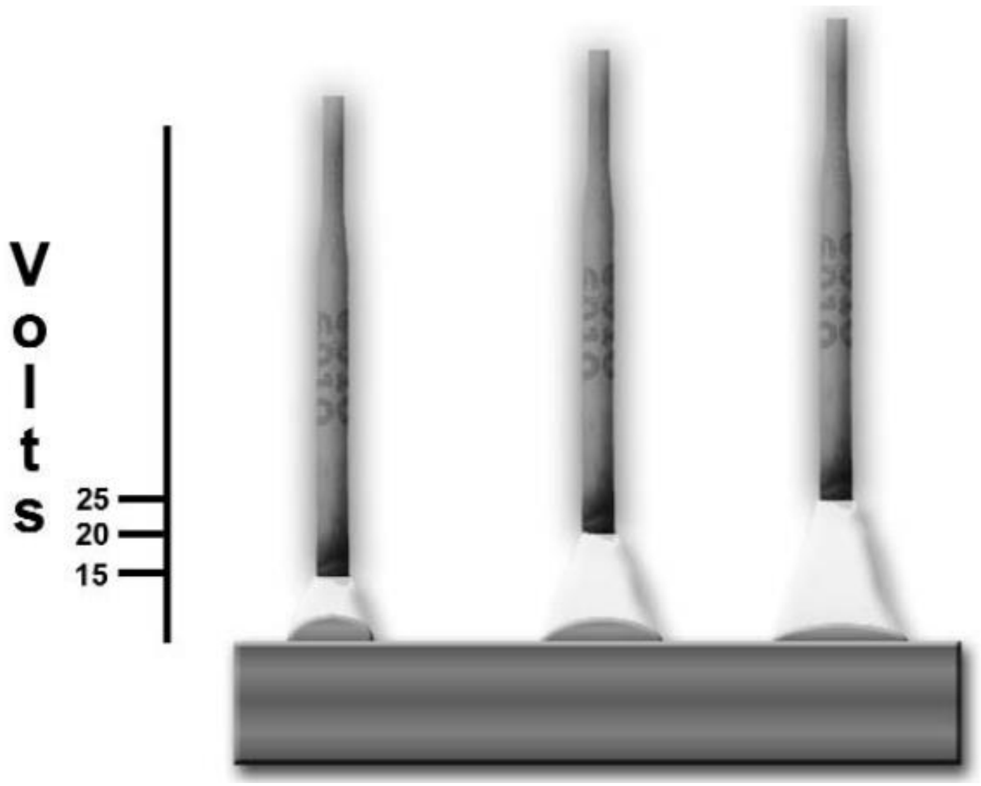
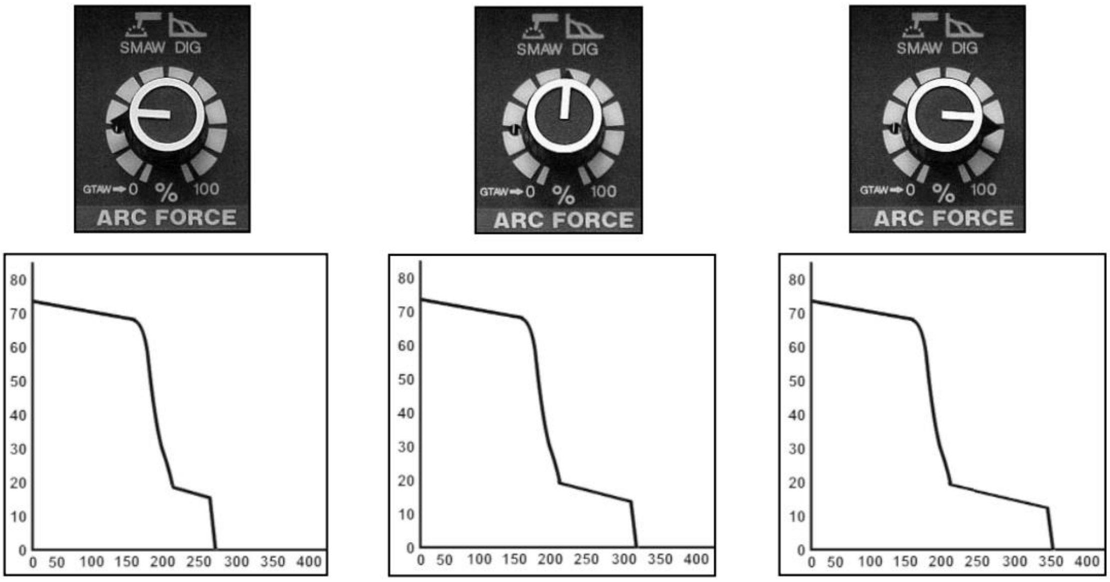


Figure 2.7: **Arc Length-Arc Voltage**

Arc control may be variable - the user may set the level of extra amperage to be supplied. The scale surrounding the arc control knob is used as a reference (it does not reflect actual amperage). As this knob is turned from 0 towards 100, the amount of additional amperage is increased. When arc control is set at 100, maximum additional amps are supplied.



25% Arc Force 50% Arc Force 75% Arc Force

Figure 2.8 : Arc Force Adjustments

Each welder will have his or her own ideas on where to set the arc control for different types of electrodes.Some general recommendations are:

- For open root welds on plate or pipe, generally an EXX10 or EXX11 electrode would be selected for the first pass. During the first pass the welder is trying to achieve full penetration. By adding arc control, usually toward the high end of the scale, the welder has the ability to control amperage by arc length. When the operator requires deeper penetration, all that needs to be done is to decrease arc length and the amperage will increase, causing increased penetration.

- For electrodes that are not used for open root welds, the welder should increase arc control to the point where the electrodes don't stick at the start or while welding

In summary, arc control (to the level set) only comes into the welding circuit when load voltage is below 19 volts. Arc control can keep electrodes from sticking, can increase penetration, and can eliminate a lot of operator frustration.

Hot Start

When this feature is selected, 70 to 100 additional amps are automatically provided for 1/10 of 1 second at the arc starting. This provides a higher starting amperage than the set amperage value and is in addition to the arc force amperage.

2.3. MMAW processes and properties

2.3.1 Definition and general description

Manual Metal Arc Welding (MMAW) is an arc welding process in which coalescence of metals is produced by heat from an electric arc that is maintained between the tip of a consumable covered electrode and the surface of the base metal in the joint being welded.

2.3.2 MMA welding process properties and its Application

Shielded Metal Arc welding is one of the most widely used processes, particularly for short welds in production, maintenance and repair work, and for field construction. The following are advantages of this process:

1. The equipment is relatively simple, inexpensive, and portable.
2. The filler metal, and the means of protecting it and the weld metal from harmful oxidation during welding, are provided by the covered electrode.
3. Auxiliary gas shielding or granular flux is not required.
4. The process is less sensitive to wind and draft than gas shielded arc welding processes.
5. It can be used in areas of limited access.
6. The process is suitable for most of the commonly used metals and alloys.

2.3.3 PRINCIPLES OF OPERATION

Shielded Metal Arc welding employs the heat of the arc to melt the base metal and the tip of a consumable covered electrode. The electrode and the work are part of an electric circuit. This circuit begins with the electric power source and includes the welding cables, an electrode holder, a workpiece connection, the workpiece (weldment), and an arc welding electrode. One of the two cables from the power source is attached to the work. The other is attached to the electrode holder.

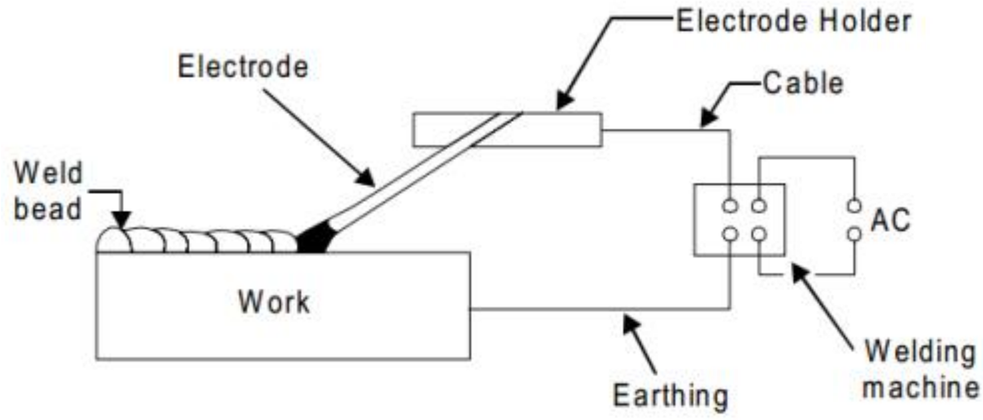


Figure 2.9: The basic principle of arc welding

Self-Check -2	Written Test

Directions: Multiple choice

Instruction: Choose the letter of the best answer and write on the space provided

1. Which one of the following cannot affect weld quality?
   A. Welding current
   B. Travel speed
   C. Arc length
   D. Welding electrode
   E. None of the above
2. Which type of polarity connection is better for creating good penetration
   A. DCEN
   B. DCEP
   C. Straight polarity
   D. None of the above
3. Which one of the following is not an aspect while setting welding current?
   A. Thickness of plate
   B. Welding position
   C. Length of cable required:
   D. Ease of arc initiation and maintenance needed even with low current:
   E. None of the above

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Information Sheet-3	Selecting electrodes

3.1. 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 may be of following two types:

A. **Bare Electrodes:**

These are available in the form of continuous wire or rods. They must be used only with straight polarity in D.C. welding. Bare electrodes do not provide any shielding to the molten metal pool from atmospheric oxygen and nitrogen.

Hence, the welds obtained by these electrodes are of lower strength, lower ductility and lower resistance to corrosion. They find limited use in minor repair and poor quality work. They used to weld wrought iron and mild steel. In modern practice they are not used or rarely used. They are also known as plain electrodes.

B. Coated Electrodes:

The core of the coated electrode consists of either a solid metal rod of drawn or cast material or one fabricated by encasing metal powders in a metallic sheath. The core rod conducts the electric current to the arc and provides filler metal for the joint. The primary functions of the electrode covering are to provide arc stability and to shield the molten metal from the atmosphere with gases created as the coating decomposes from the heat of the arc. These are sometimes also called as conventional electrodes. A coating (thin layer) of flux material is applied all-round the welding rod, and hence termed as coated electrode. Flux chemically react with the oxides present in the metal and forms a low melting temperature fusible slag.

The slag is float on the top of the weld and can easily be brushed off after solidification of weld.

The shielding employed along with other ingredients in the covering and the core wire, largely controls the mechanical properties, chemical composition, and metallurgical structure of the weld metal, as well as the arc characteristics of the electrode. The composition of the electrode covering varies according to the type of electrode.

In addition to improving the mechanical properties of the weld metal, electrode coverings can be designed for welding with alternating current (ac). With ac, the welding arc goes out and is re-established each time the current reverses its direction. For good arc stability, it is necessary to have a gas in the arc stream that will remain ionized during each reversal of the current. This ionized gas makes possible the re-ignition of the arc. Gases that readily ionize are available from a variety of compounds, including those that contain potassium. It is the incorporation of these compounds in the electrode covering that enables the electrode to operate on ac.

To increase the deposition rate, the coverings of some carbon and low alloy steel electrodes contain iron powder. The iron powder is another source of metal available for deposition, in addition to that obtained from the core of the electrode. The presence of iron powder in the covering also makes more efficient use of the arc energy. Metal powders other than iron are frequently used to alter the mechanical properties of the weld metal.

The thick coverings on electrodes with relatively large amounts of iron powder increase the depth of the crucible at the tip of the electrode. This deep crucible helps to contain and direct the heat of the arc and permits the use of the drag technique (described in the next paragraph) to maintain a constant arc length. When iron or other metal powders are added in relatively large amounts, the deposition rate and welding speed usually increase.

Iron powder electrodes with thick coverings reduce the level of skill needed to weld. The tip of the electrode can be dragged along the surface of the work while maintaining a welding arc. For this reason, heavy iron powder electrodes frequently are called drag electrodes. Deposition rates are high, but, because slag solidification is slow, these electrodes are not suitable for out-of-position use.

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.

3.2. Selection factors for electrodes and their designation

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 welding steel, the 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 — 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.

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.

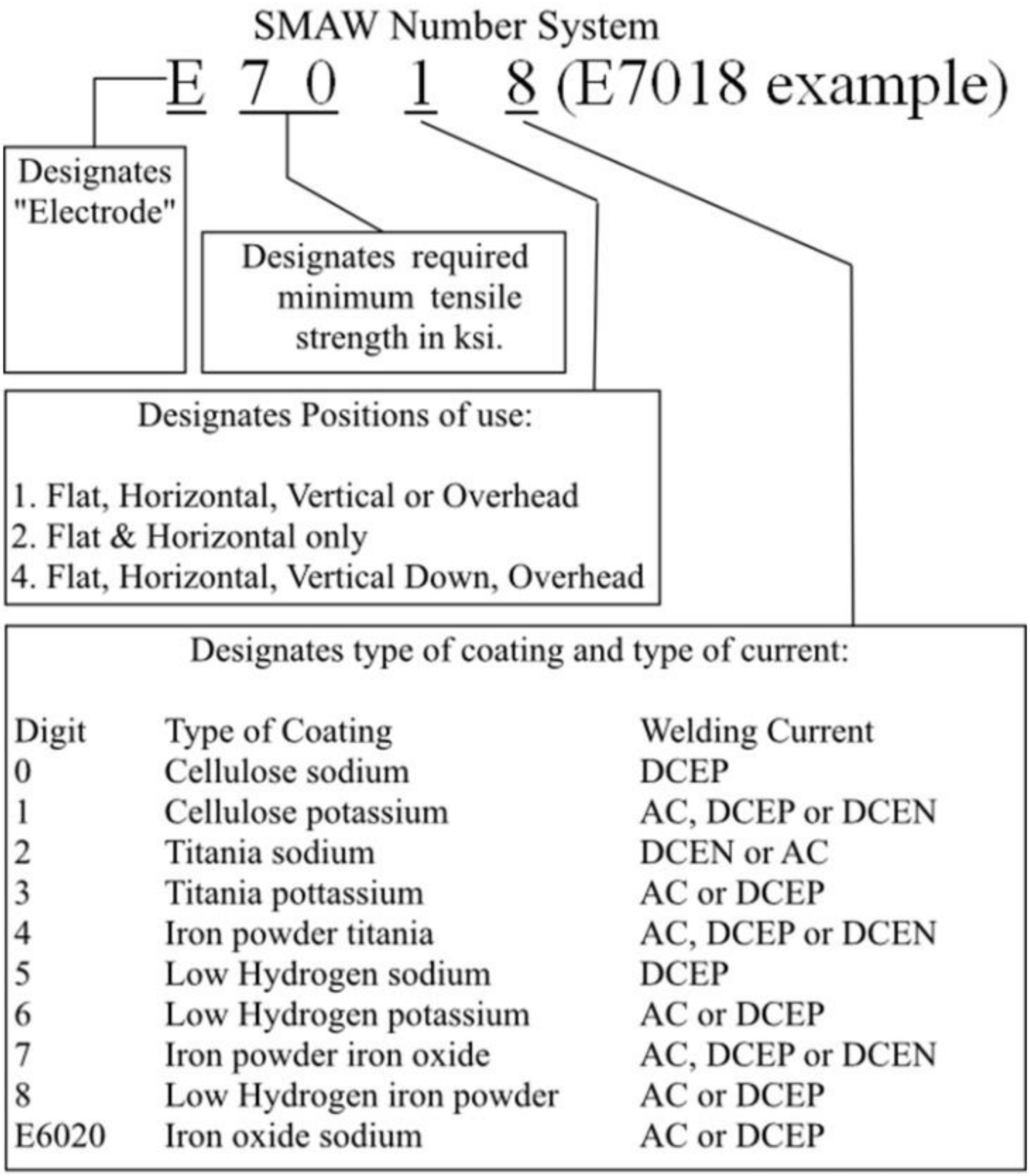
Electrodes are classified according to type of coating, composition of the weld metal and operating characteristics. The numbering system is started with "E" for electrode and then followed by a four digit number each number in the four number sequences has a specific meaning.

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

➢ Ex. Aluminum, Copper, & Brass

3.3. **Numerical designation of coated electrode**



3.4. Storage and Conditioning of Electrodes

A. Basic 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.

B. Other than basic electrodes

All other than basic electrodes shall be stored in warm and dry conditions and kept free from oil, grease, and other deleterious matter once they have been removed from their containers and packages. Electrodes that have been wet shall be discarded.

Position

The welding shall be done preferably in the flat position, but other positions such as orizontal, vertical and overhead are permissible providing the proper Data Sheets are supplied and approved.

Preheat

The minimum preheat before welding will comply with Table 5.3 of CSA Standard W59. Minimum preheat to be maintained or exceeded during welding. If welding is interrupted for some time so that the temperature of the base metal falls below the minimum preheat temperature, then arrangements will be made to preheat again prior to recommencing welding. The weldment shall be allowed to cool to the ambient temperature, without external quench media being supplied. In other words, do not cool using water or by immediate placement in frigid conditions which will cause a quick temperature change.

Self-Check -3	Written Test

Direction: Short answer items

Instruction: Briefly answer the following questions

1. What is the importance of the flux coating on a welding electrode?
2. What does an electrode numerical designation: **E60123** mean?
3. Mention the five categories of electrodes based on their composition.
4. How can store and condition electrodes?

***Note:* Satisfactory rating – 3 and 4 points** **Unsatisfactory - below 3 and 4 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: _____________

Name: ___________________________ Date: ________________

Information Sheet-4	Preparing and cleaning materials

4.1 Preparation of material

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 or veed out 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.

4.2 Setting the work piece

Once the selected work piece is prepared and cleaned, the next step is to tap the pieces to be joined after slightly striking electric arc on the way to checking whether the right amperage is set. Moreover, the tapped pieces should be positioned and clamped to a system of fixture. Generally the following should be considered while setting the work piece.

- Set the job in a flat position on the welding table.

- Ensure there is good electrical contact between the job and the welding table.

4.3. Striking and maintaining an Arc

Striking an arc is a basic operation in arc welding. It will occur every time the welding is to be started. It is an essential basic skill to learn in arc welding.

A. Scratching method:

- Hold the electrode about 25 mm above the job piece at one end perpendicular to surface
- Bring the welding screen in front of your eyes.
- Ensure safety apparatus is worn.
- Strike the arc by dragging the electrode quickly and softly across the welding job, using wrist movement only.
- Withdraw the electrode approximately 6 mm from the surface for a few seconds and then lower it to (approximately) 4mm distance.
- If the arc has been properly struck, a burst of light with a steady sharp crackling sound will be produced.

B. Tapping method:

❖ Strike the arc by moving the electrode down to touch the job surface lightly.

❖ Move the electrode slowly up approximately 6mm for a few seconds and then lower it to approximately 4 mm from the surface.

❖ The tapping method is generally recommended as it does not produce pit marks on the job surface

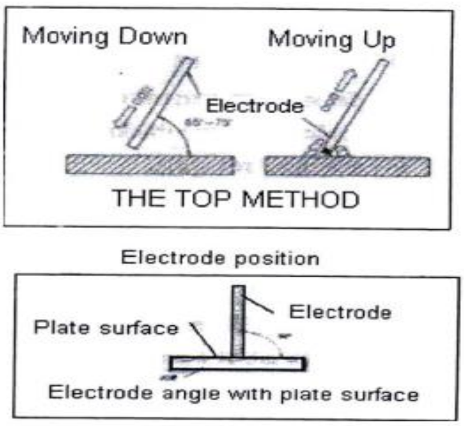


Figure 4.1: scratching and tapping methods

Self-Check -4	Written Test

Directions: Short answer items

Instruction: Briefly answer the following questions

1. What is the importance of cleaning a work piece before commencing welding?
2. What are the cleaning tasks to be performed before welding operation?
3. List the basic procedures to set up the work piece for welding.
4. List some cleaning equipments used after welding.
5. List some cleaning equipments used after welding.

***Note:* Satisfactory rating – 3 points** **Unsatisfactory - below 3 and 4 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ____________

Rating: _____________

Name: ___________________________ Date: ________________

Short Answer Questions

Information Sheet-5	Welding materials

5.1 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 workpiece with earthing 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 workpiece 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: below . This process employs coatings or fluxes to prevent the weld pool from the surrounding atmosphere.

1. Switch box.
2. Secondary terminals
3. Welding machine.
4. Current reading scale.
5. Current regulating hand wheel.
6. Leather apron.

7.Asbestos hand gloves.

8. Protective glasses strap

9. Electrode holder.

10. Hand shield

11. Channel for cable protection.

12. Welding cable.

13. Chipping hammer.

14. Wire brush.

15. Earth clamp.

16. Welding table (metallic).

17. 17) Job.

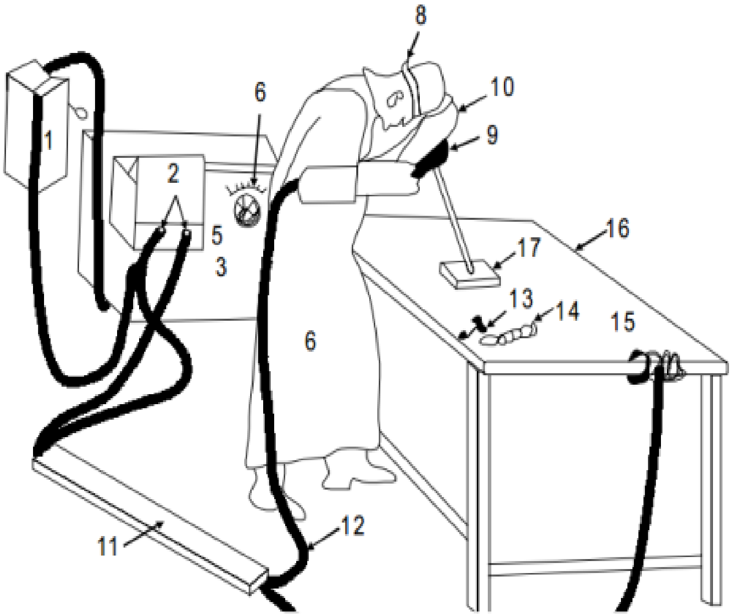


Figure 5.1:.The basic elements of arc welding equipment

5.2 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

I. 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

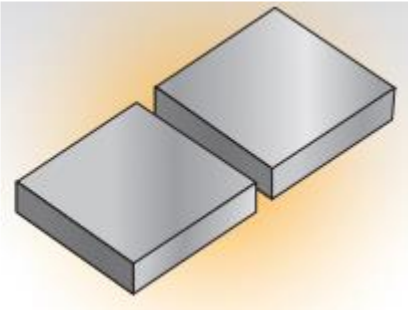


Figure 5.2: butt joint

II. 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

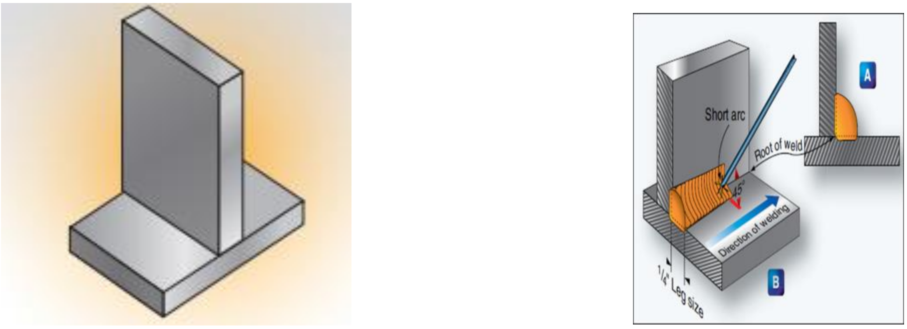
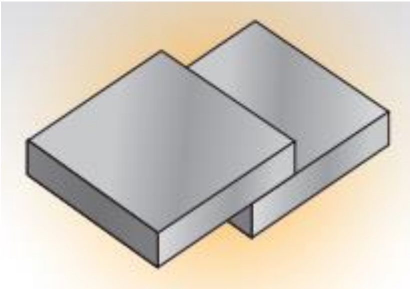


Figure 5.3: T-joint

III. 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



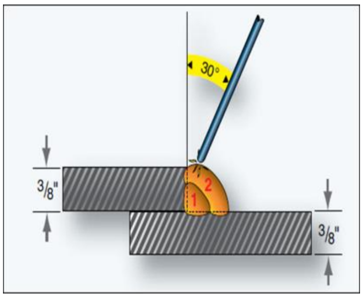


Figure 5.4: Lap joint

IV. 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

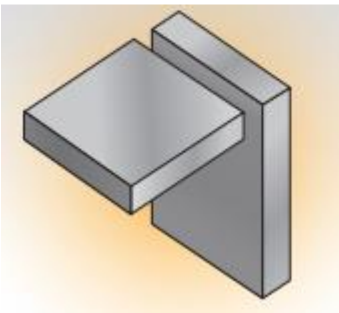


Figure 5.5: Corner joint

V. 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

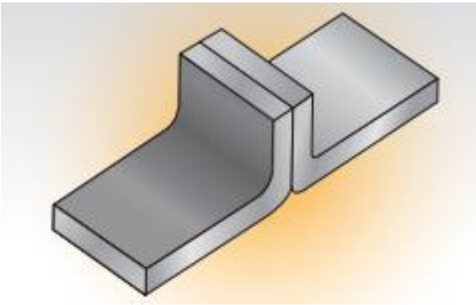


Figure 5.6: Edge joint

5.3 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.

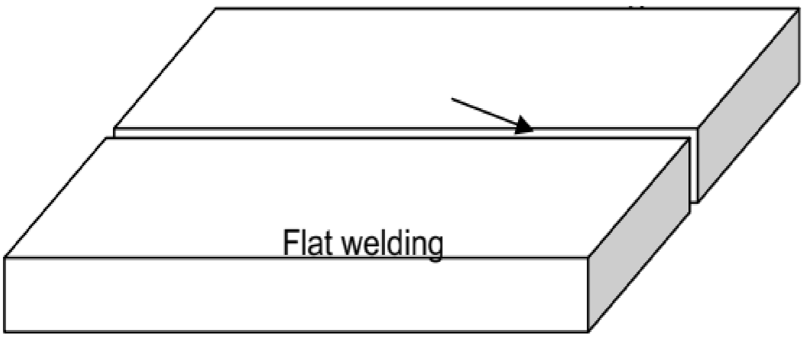


Figure 5.7:. Scheme of placement of components to be welded for flat welding

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 5.8] 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.

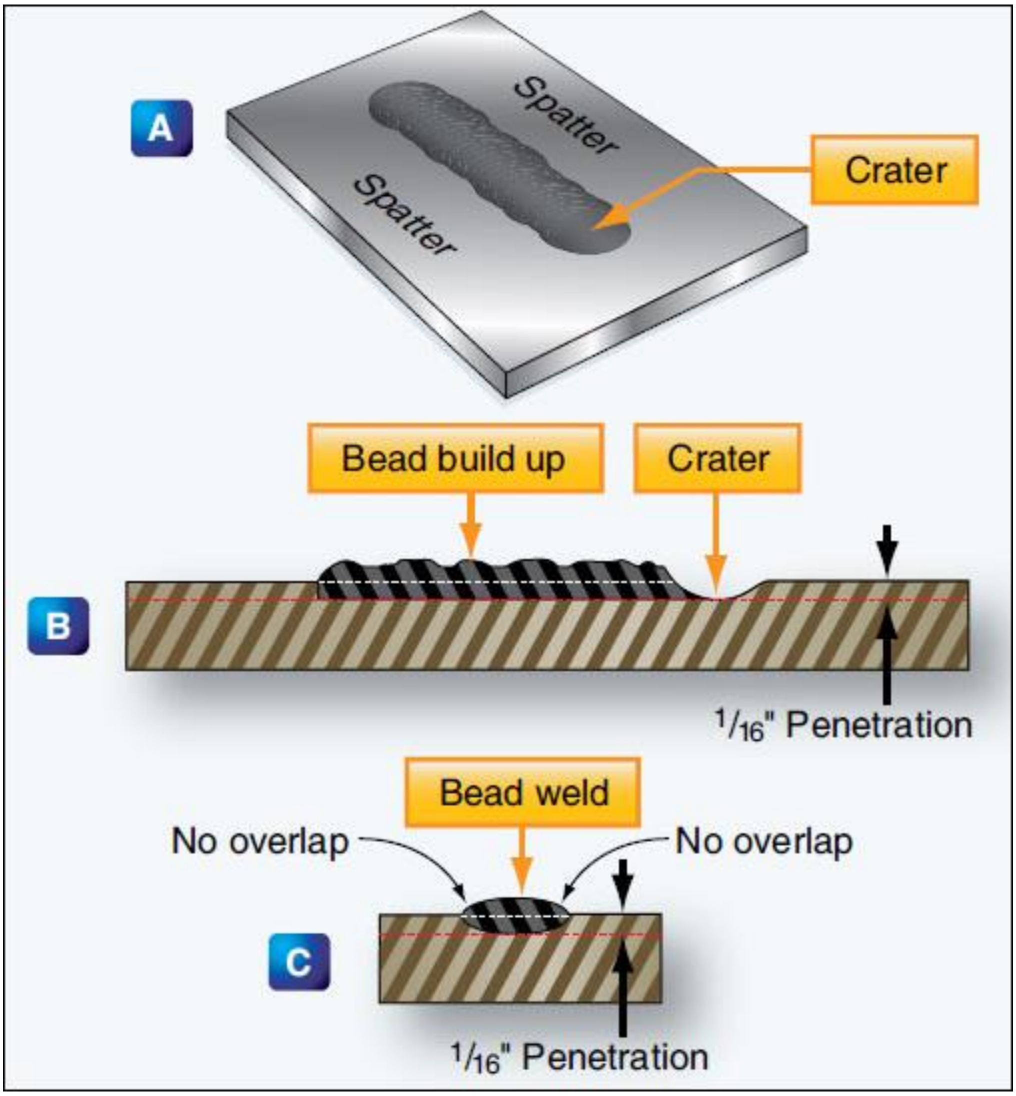


Figure 5.8: Bead weld

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 5.9.

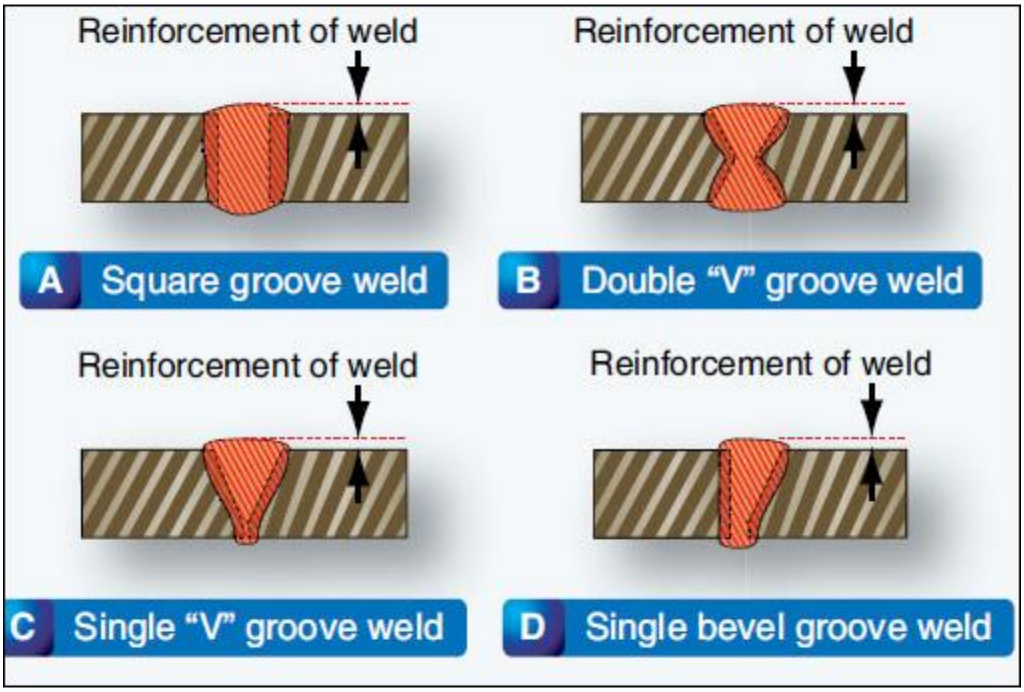


Figure 5.9: Groove weld

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 5.10]

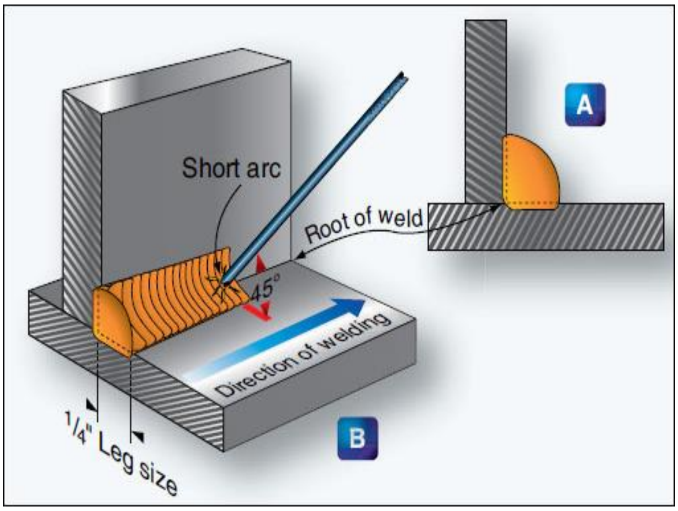


Figure 5.10: Fillet weld

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 5.11]

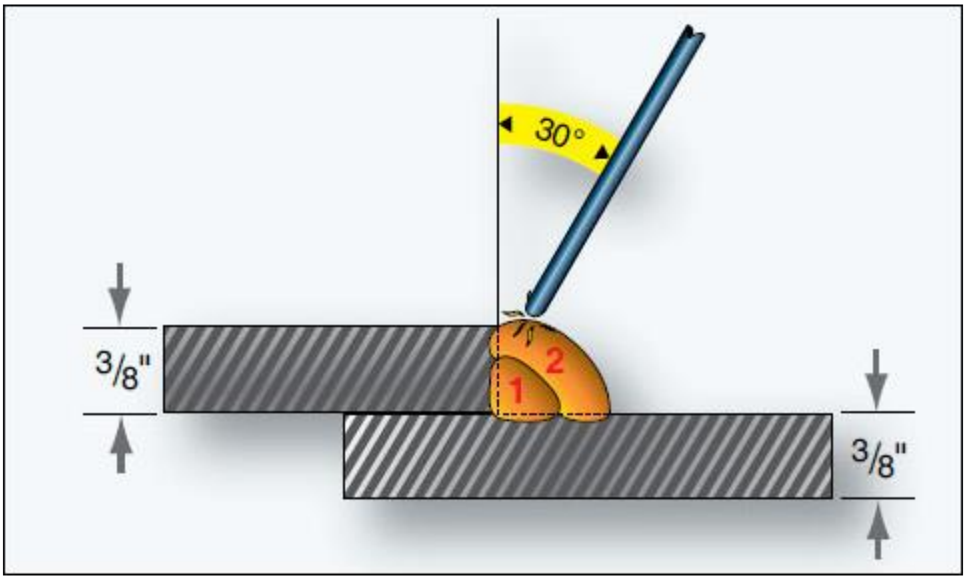


Figure 5.11: Lap joint weld

2. Horizontal welding

In horizontal welding, plates to be welded are placed in vertical plane while weld bead is deposited horizontally (Figure 5.12.). 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.

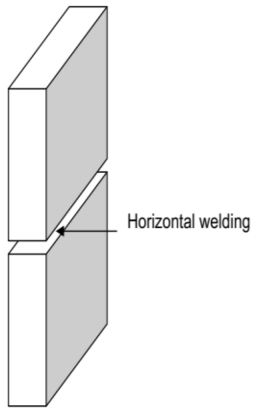


Figure 5.12:. Scheme of placement of components to be welded for horizontal welding

3. Vertical welding

In vertical welding, plates to be welded are placed on the vertical plane and weld bead is also deposited vertically (Figure 5.13.). 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.

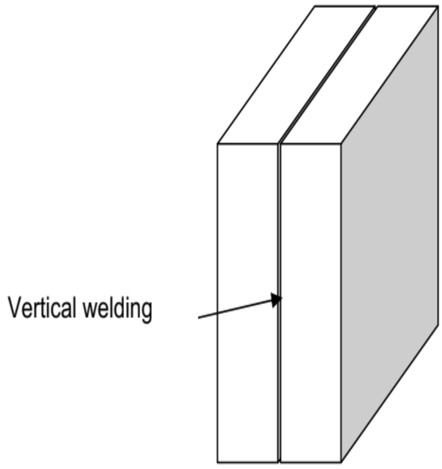


Figure 5.13: Scheme of placement of components to be welded for vertical welding

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 5.14.). 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.

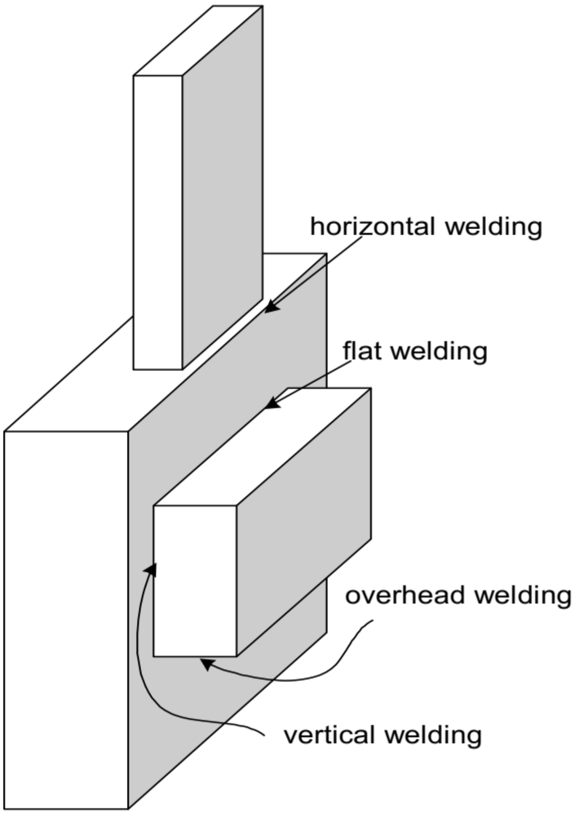


Figure 5.14. Scheme of placement of components to be welded for different types of welding positions including overhead welding

After preparing and setting the materials, the next step is welding and producing output as indicated in the following figure 5.15.

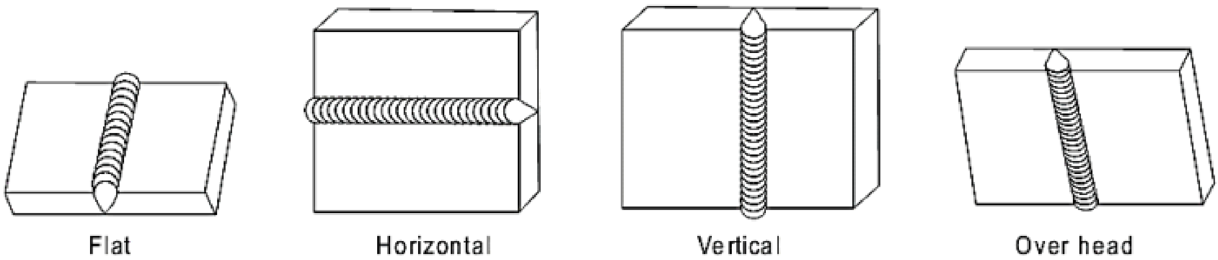


Figure 5.15: Different welding positions applied on butt joint.

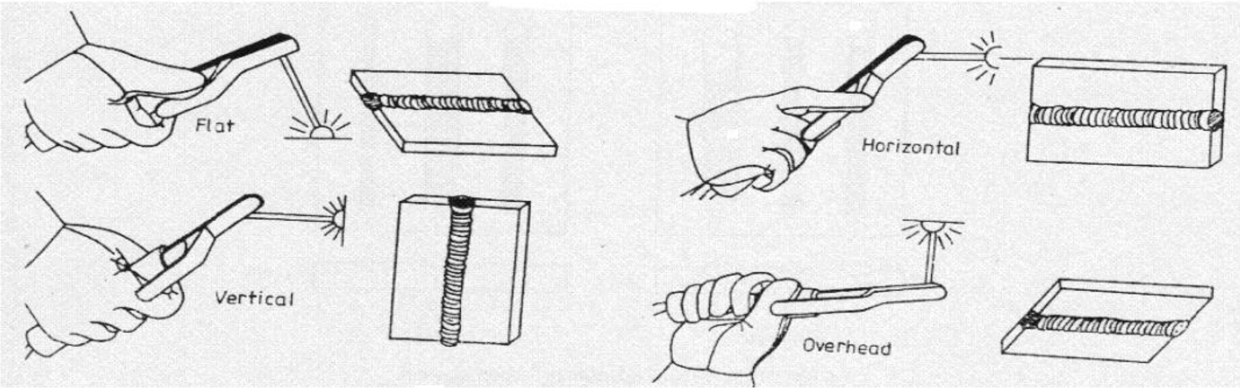


Figure 5.16: Application of butt joint welding at different positions

Self-Check -5	Written Test

Directions: Short answer items

Instruction: Briefly answer the following questions

1. List the five types of welding joints.
2. What are the major types of welding positions? Explain with drawing
3. What is the difference between bead weld and groove weld?
4. With what type of welding joint is high penetration impossible?
5. While fillet welding the T-joint, how much should be the angle of the electrode from the plate face?

***Note:* Satisfactory rating – 3 points** **Unsatisfactory - below 3 and 4 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________
Rating: ____________

Name: _________________________ Date: _______________

Operation Sheet 1	Setting up arc welding equipment

Basic procedures to set up a welding equipment

Step-1: Check the working of power source for the welding machine.

Step-2: Remember electricity is a good servant but a bad master.

Step-3: Call an electrician for solving any electrical problems.

Step-4: Connect the welding cables with the welding machines.

Step-5: Ensure that the cable connections are clean, dry, nd are attached to the proper terminals of the machine.

Step-6: Attach tightly the earth cable with the welding table at the proper place.

Step-7: Keep the electrode-holder at a safe place

Step-8: If the machine is on D.C. power, connect the cables in correct polarity. Polarity means changing of +ve and -ve to the electrode is called polarity.

Operation Sheet- 2	To practice straight beads on the given mild steel flat piece in down hand position by arc welding.

Procedures to practice straight beads on mild steel piece

Step-1: Copy the given working drawing in the work record.

Step-2: Cut the work piece as per the drawing.

Step-3: File the work piece to the dimensional accuracy**.**

Step-4: Kept the work piece on the welding table in the down hand position.

Step-5: Set the ampere of the machine and use protective cloth , select suitable electrode **and proper shield.**

Step-6: Remove the slag and spatters using the chipping hammer and wire brush.

Step-7: After completion of weld , the weld bead should be inspected.

Operation Sheet- 3	To make a T-joint using the given two mild steel pieces by arc welding.

Procedures to make a T-joint with mild steel pieces

Step-1: Copy the given working drawing in the work record.

Step-2: Cut the work piece as per the drawing.

Step-3: File the work piece to the dimensional accuracy.

Step-4: Kept the work piece on the welding table in the down hand position.

Step-5: Set the ampere of the machine and use protective cloth , select suitable electrode and proper shield.

Step-6: Tack welds the two ends of the work piece and checks the alignment.

Step-7: Remove the slag and spatters using the chipping hammer and wire brush.

Step-8: After completion of weld , the weld bead should be inspected.

Operation Sheet-4	To make a Butt joint using the given two mild steel pieces by arc welding.

Procedures to make butt joint

Step-1: The given M.S pieces are thoroughly cleaned of rust and scale.

Step- 2: One edge of each piece is believed, to an angle of 300, leaving nearly ¼ th of the flat thickness, at one end.

Step- 3: The two pieces are positioned on the welding table such that, they are separated slightly for better penetration of the weld.

Step- 4: The electrode is fitted in the electrode holder and the welding current is ser to be a proper value.

Step- 5: The ground clamp is fastened to the welding table.

Step- 6: Wearing the apron and using the face shield, the arc is struck and holding the two pieces
together; first run of the weld is done to fill the root gap.

Step -7: Second run of the weld is done with proper weaving and with uniform movement. During the process of welding, the electrode is kept at 150 to 250 from vertical and in the direction of welding.

Step -8: The scale formation on the welds is removed by using the chipping hammer.

Step- 9: Filling is done to remove any spanner around the weld.

LAP Test	Practical Demonstration

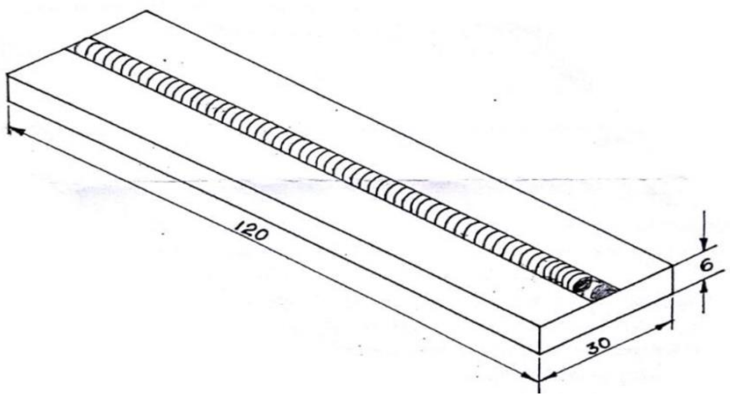
Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 5-7 hours

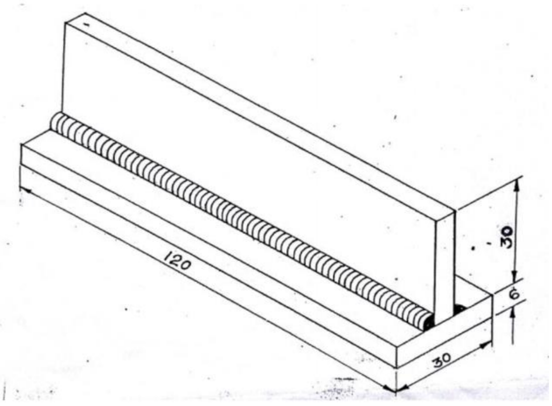
Task 1: set up the arc welding equipment

Task 2: produce a straight bead on the mild steel as described on the working drawing 1



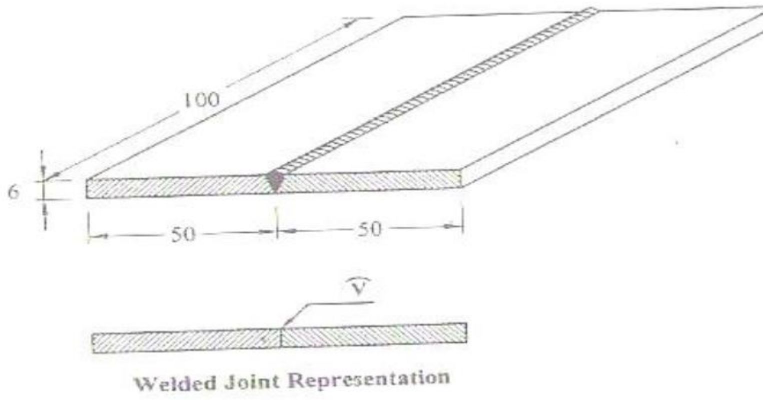
Working drawing 1

Task 3 : Make a T-joint using mild steel pieces dimension as indicated on working drawing 2



Working drawing 2

Task 4: Make a Butt joint using mild steel pieces dimension as indicated on working drawing-3



Working drawing-3

Information Sheet-6	Cleaning Welding seams

7. Cleaning welding seams

Cleaning is necessary before welding, during welding (interpass) 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 discolour and overheat the metal. Rubber and resin bonded wheels are satisfactory. Wheels should be dressed regularly to prevent them becoming loaded thereby producing objectionable scratches. In any blasting process steel shot shall not be used.

Self-Check -6	Written Test

Directions: Short answer items

Instruction: Briefly answer the following questions

1. Mention the three methods of cleaning welding seams
2. What is the importance of cleaning weld piece?
3. What are to be cleaned from welding seams?

Note: **Satisfactory rating – 3 points** **Unsatisfactory - below 3 and 4 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Basic metal works

Level-I

Learning Guide-46

Unit of Competence:	**Perform routine arc welding**
Module Title:	**Performing routine arc welding**
LG Code:	**INDBMW1M13 LO3-LG-46**
TTLM Code:	**INDBMW1M13 TTLM 1019v1**

LO 3: Assure quality and clean up

Instruction Sheet	Learning Guide #46

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

- Cleaning and inspecting welding seams
- Measuring joints
- Cleaning and maintaining work area and welding equipment

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

- Clean and inspect welding seams
- Measure joints
- Clean and maintain work area and welding equipment

Learning Instructions:

13. Read the specific objectives of this Learning Guide.
14. Follow the instructions described below 3 to 6.
15. Read the information written in the information "Sheet 1, Sheet 2, Sheet 3 and Sheet 4".
16. Accomplish the "Self-check 1, Self-check t 2, Self-check 3 and Self-check 4" **in page -6, 9, 12 and 14** respectively.
17. If you earned a satisfactory evaluation from the "Self-check" proceed to "Operation Sheet 1, Operation Sheet 2 and Operation Sheet 3 " **in page -15.**
18. Do the "LAP test" **in page – 16** (if you are ready).

Information Sheet-1	Cleaning and inspecting welding seams

1.11. Cleaning welding seams

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.

1.12. 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
6. Lamellar Tearing

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 the surface of the metal to be welded or damp consumables.

It is found in the shape of sphere or as elongated pockets. The region of distribution of the porosity is random and sometimes it is more concentrated in a certain region. By storing all the consumables in dry conditions 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 the weld surface before welding and by selecting the appropriate joint design and electrodes, a better weld can be obtained. On extending the fusion zone 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 materials in the weld zone the inclusions are occurred. Inclusions occur while joining thick plates in several runs using flux cored or flux coated rodsand the slag covering a run is not totally removed after every run and before the next run starts. By maintaining a clean surface before the run is started, providing sufficient space for the molten weld metal between the pieces to be joined, the inclusions can be prevented.

4. Cracking

Due to thermal shrinkage, strain at the time of phase change, cracks may occur in various directions and in various locations in the weld area. Due to poor design and inappropriate procedure of joining high residual stresses, cracking is observed. A stage-wise pre-heating process and stage-wise slow cooling will prevent such type of cracks. This can greatly increase the cost of welded joints. Cracks are classified as hot cracking and hydrogen induced cracking. A schematic diagram of centerline crack is shown below fig. 1.1.

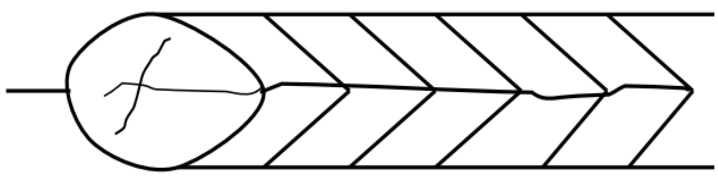


Fig. 1.1 Schematic diagram of centerline crack

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

5. Undercutting

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

6. **Lamellar Tearing**

Due to nonmetallic inclusions, the lamellar tearing occurs through the thickness direction. This is more evidently found in rolled plates. As the fusion boundary is parallel to the rolling plane in T and corner joints, the lamellar tearing occur. By redesigning the joint and by buttering the weld area with ductile material, the lamellar tearing can be minimized.

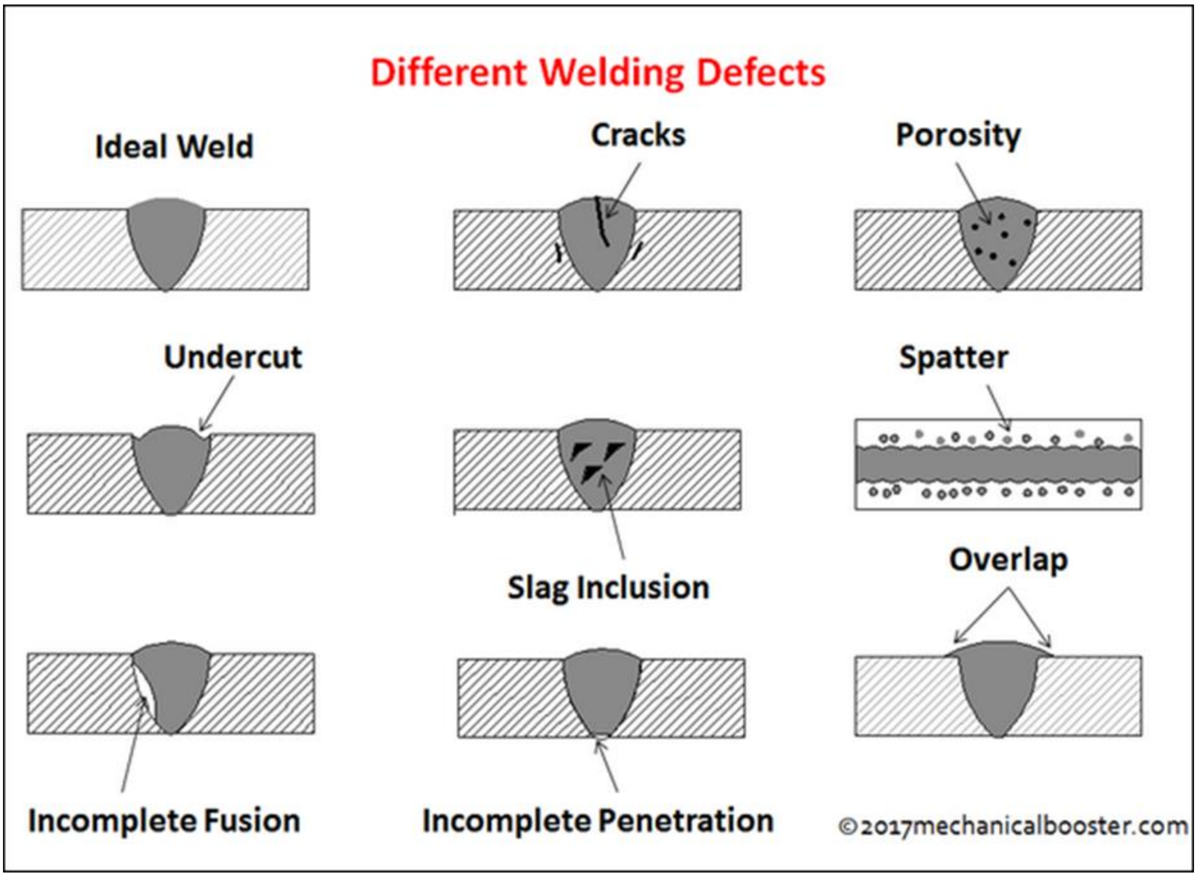


Figure 1.1: Different welding defects

- 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.

1.13. Inspecting and testing 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.

1.3.1 Distructive Material test

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 1.2:

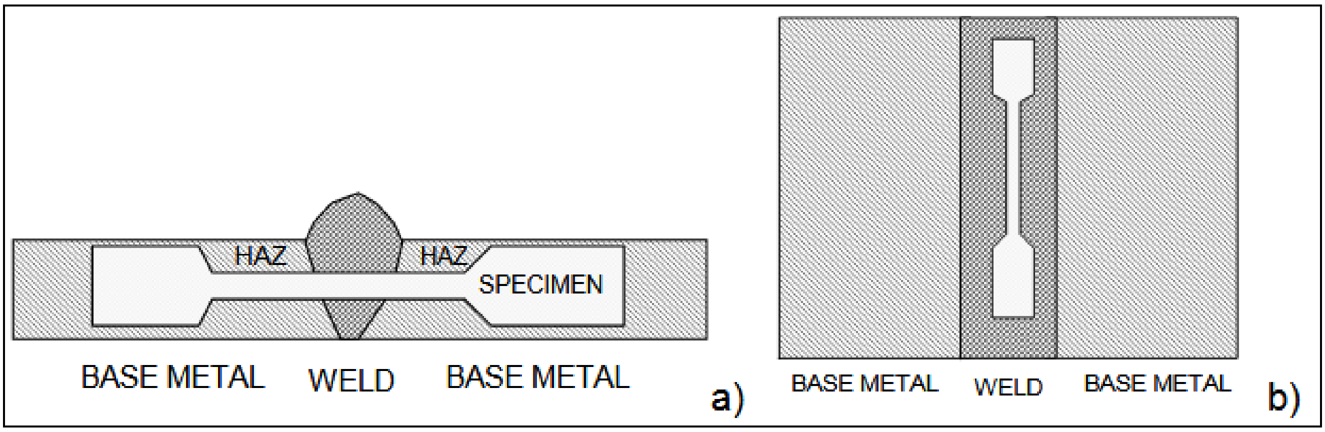


Figure 1.2. Schematic of tensile specimens from a) transverse section of weld joints and b) all weld specimen

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 1.3). Tests results must includes 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

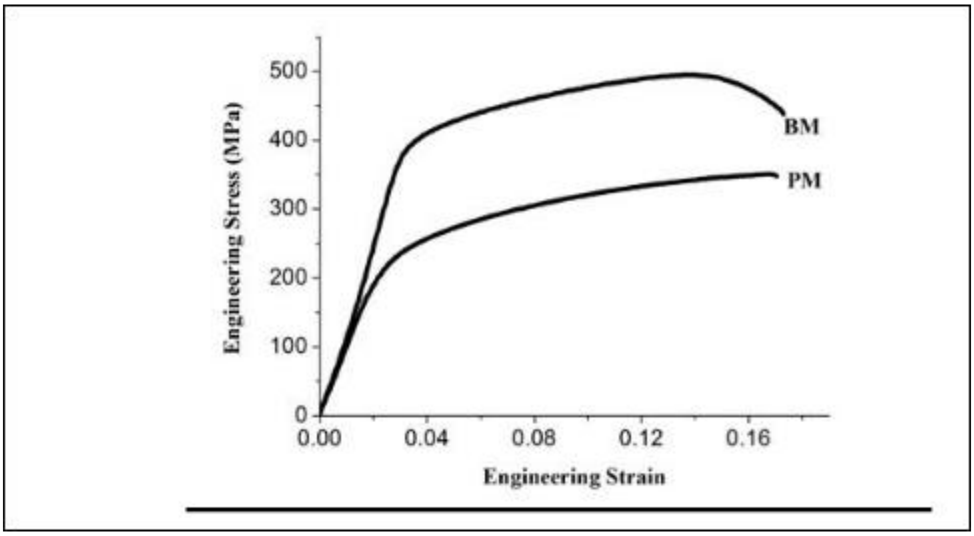


Figure 1.3: Typical stress stain diagram for AA 7039 in as received (BM) and friction stir prcoessed (PM) condition

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 1.4 and 1.5). 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 1.5.

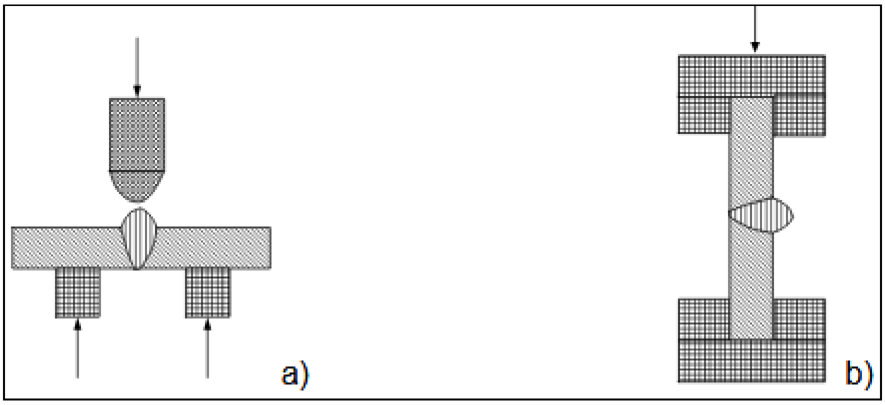


Figure 1.4: Schematics of free bend tests

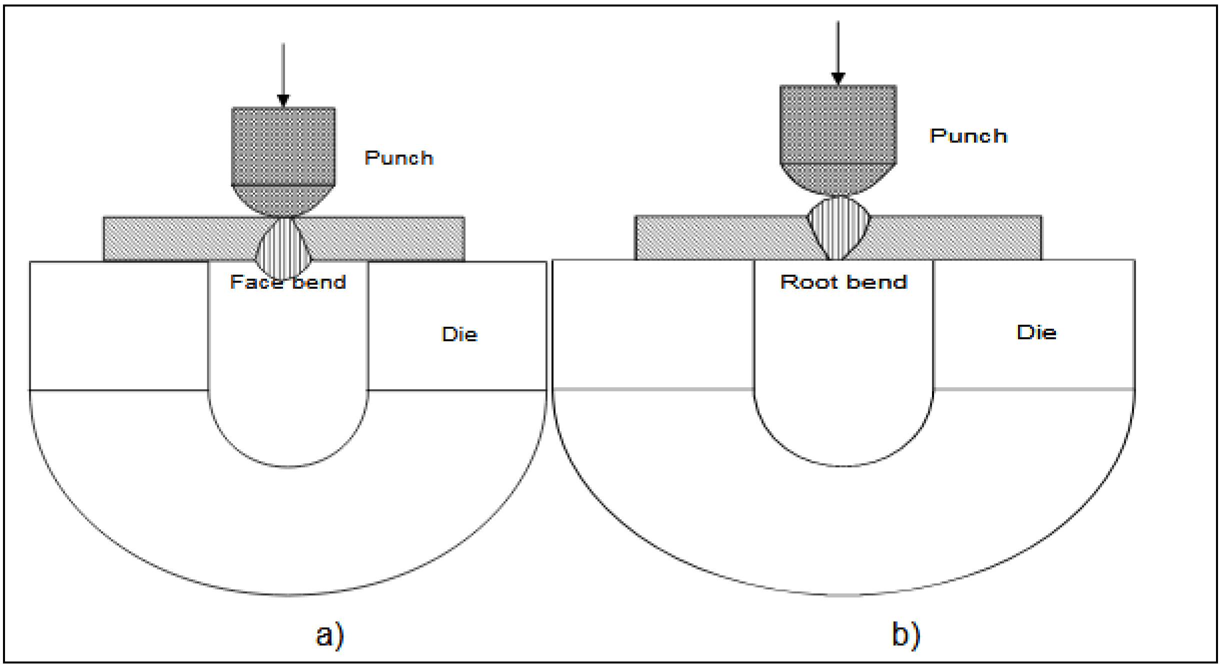
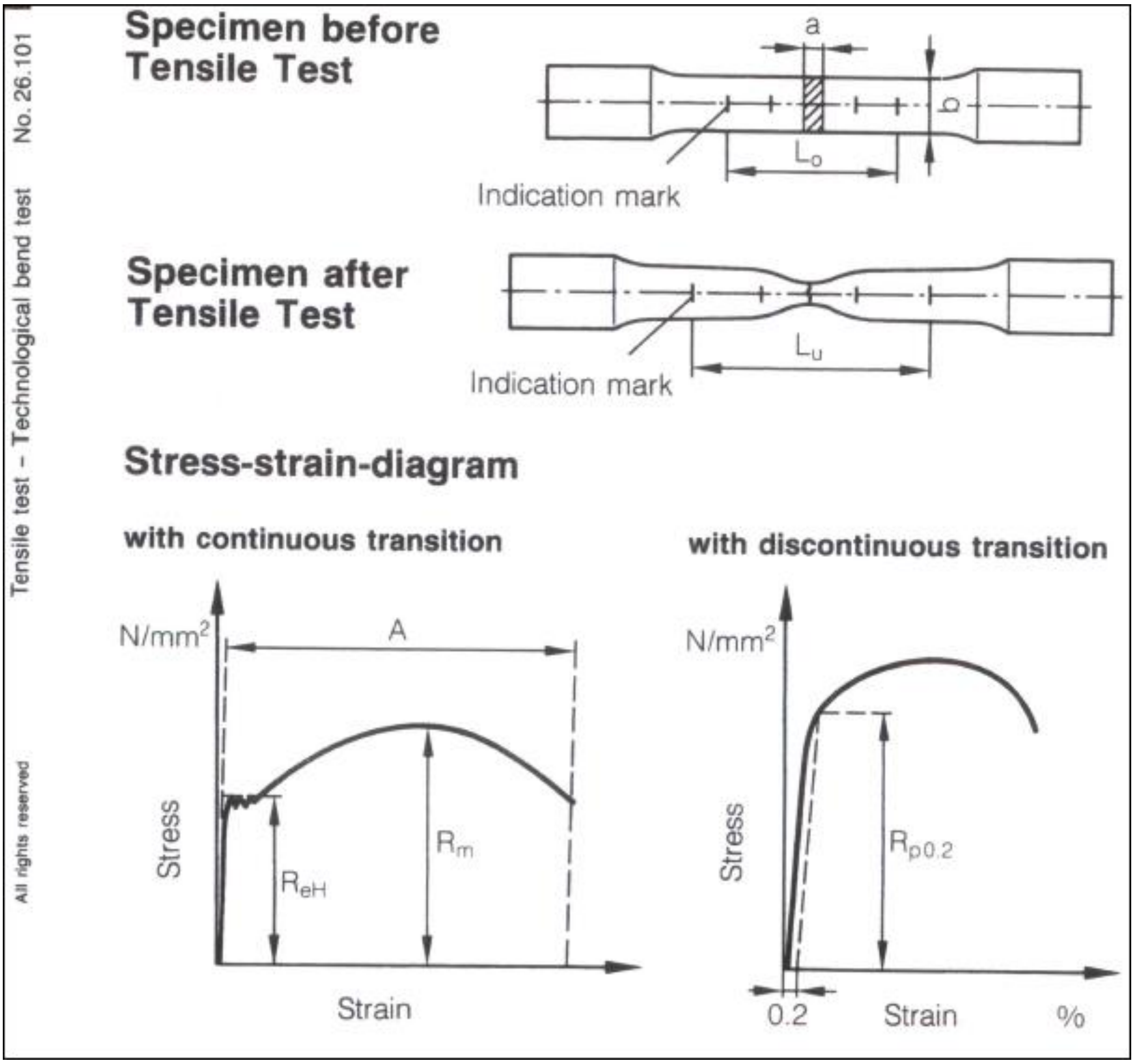


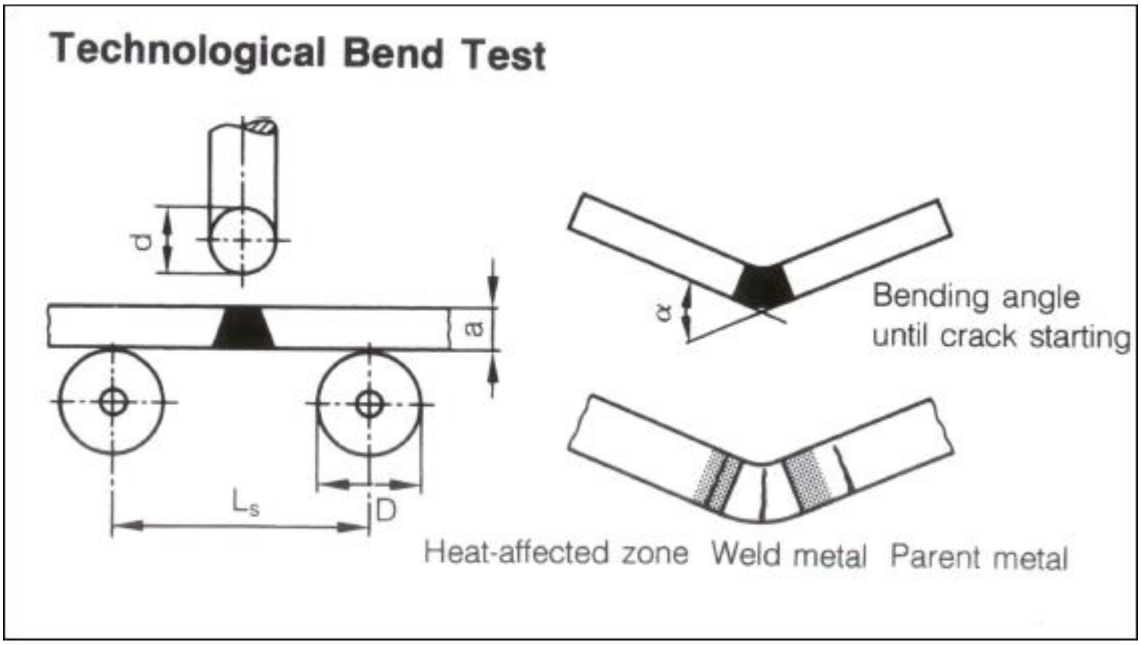
Figure 1.5 :Schematics of guided bend tests a) face bend and b) root bend.

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 1.6). 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.




Technological Bend Test
d
a
Ls
D
α
Bending angle until crack starting
Heat-affected zone
Weld metal
Parent metal

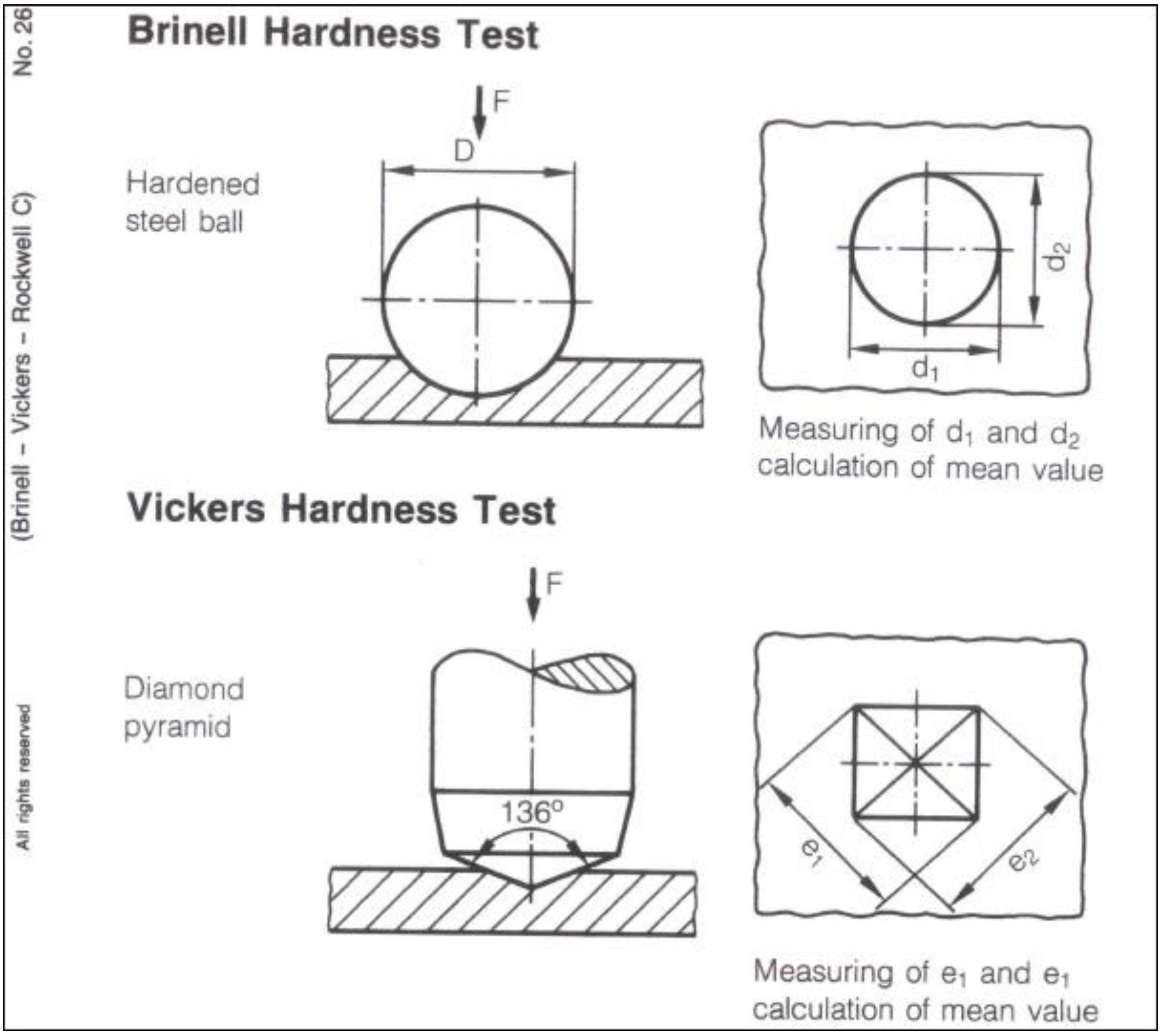

(Brinell – Vickers – Rockwell C) No. 26
All rights reserved
Brinell Hardness Test
F
D
Hardened steel ball
d1
d2
Measuring of d1 and d2 calculation of mean value
Vickers Hardness Test
F
Diamond pyramid
136°
e1
e2
Measuring of e1 and e1 calculation of mean value

Figure 1.6:

1.3.2 Non-Destructive Testing (NDT)

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 occuring 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

Ultrasonic testing is one of the widely used and powerful techniques for nondestructive testing of materials. One of the largest applications of Ultrasonic testing in NDT is weld inspection.

ULTRASONIC TESTING

Ultrasonic testing uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more.

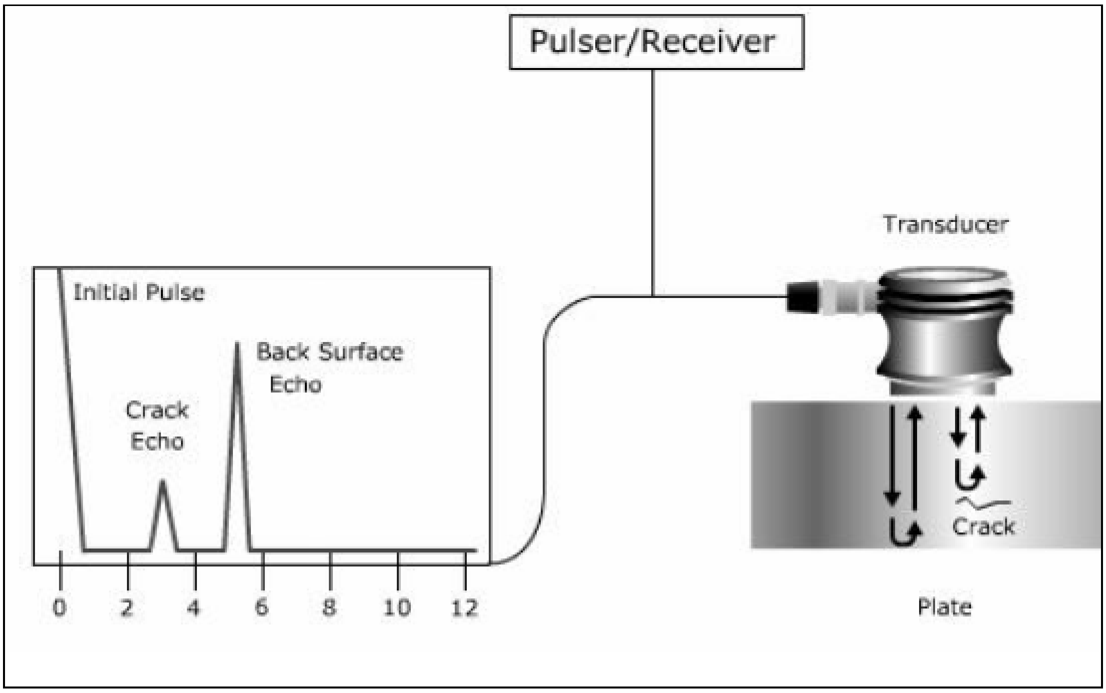


Figure 1.7 : Typical ultrasonic inspection system

Self-Check -1	Written Test

Directions: Short answer items

In**struction**: Briefly answer the following questions.

1. Mention at least five weld defects and explain the causes of each.
2. List the destructive testing methods of weld quality.
3. Mention the non-destructive testing methods of weld quality
4. What is the meaning of **Pass** in welding?
5. Which one is a widely used and powerful NDT method?

Note: **Satisfactory rating - 3 and 5 points** **Unsatisfactory - below 3 and 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet- 2	Measuring joints

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, dept of root face, convexity, smoothness of transition weld to the base metal, leg length, etc.

2.2. Measuring joints 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.

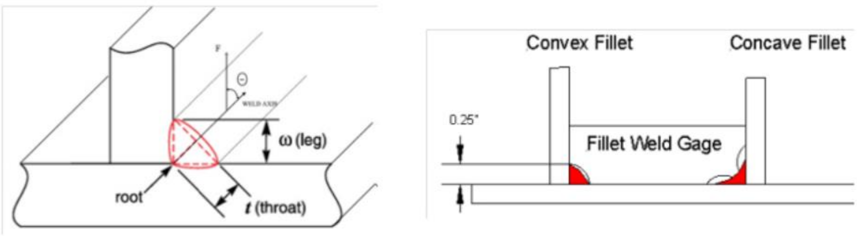


Figure 2.1: weld fillet guages

Fillet welds can be measured using a gauge set as shown in Figure 2.2, 2.3and 2.4 belowThe gauges can be used on both concave and convex fillet welds as long as the user understands how a fillet is measured. Whether measuring fillet welds or other weld features, the key to using these gauges is to make sure they are sitting flat against the surface.

Figure 2.2: V-WAC gauge

Figure 2.3:*Throat measurement with cam gauge*

Figure 2.4: 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.

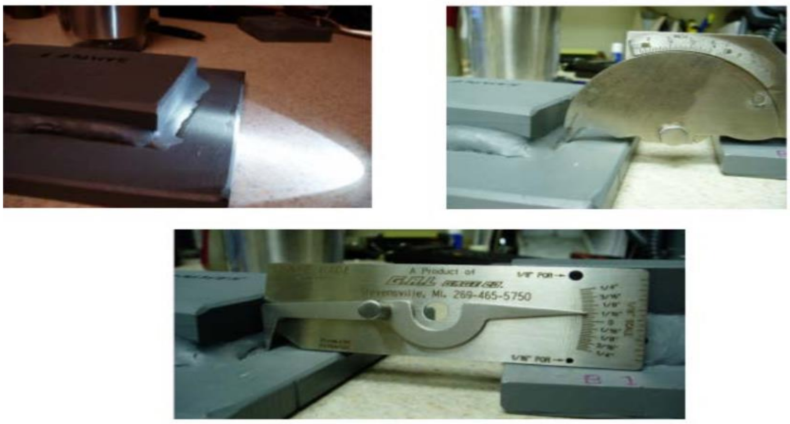


Figure 2.5: measuring undercut

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.

Figure2.6: 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.

Self-Check -2	Written Test

Directions: Short answer items

Instruction: briefly answer the following questions .

1. How can we measure welding joints?
2. Mention the equipments used to measure fillet welds
3. How can measuring defects contribute to quality control?

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Information Sheet-3	Cleaning and maintaining work area and welding equipment

3.1. Cleaning 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.

3.2 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.

3.3 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

Self-Check -3	Written Test

Directions: Short answer items

Instruction: Briefly answer the following questions

1. What are the proper procedures that should be followed before cleaning and maintaining your workshop?
2. What is preventive maintenance?
3. What are the benefits of keeping clean workshop and machinery?
4. How can machine shop layout contribute to productivity of welding shop?
5. Who is responsible to maintain the workshop and machinery clean?

***Note:* Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

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The trainers who developed this TTLM

No	Name of trainer	Qualification	Region	E-mail
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2	MULUKEN YENET	B-Level	AMHARA	mulukeynet@gmail.com
3	KABTAMU SHEWANGIZAW	A-Level	OROMIA	Kabtamushewaangizaw@gmail.com
4	YOHANNIS HAILE	B-Level	B.G.R	
5	AHMED HUSSEN	B-Level	SOMALI	abdirashidhusen@hotmail.com
6	AYSHA SHIBESHI	B-Level	AFAR	yasinmohammed459@gmail.com
7	TEKALIGN BEKELE	B-Level	SNNPR	
8	BOKA TEREFE	A-Level	OROMIA	bokaterefe@yahoo.com

This model TTLM was developed on September 04/01/2012 E.C at ADAMA