GMAW (MIG) – Welding – (40 Hours Course)

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GMAW (MIG) – Welding – (40 Hours Course)

With technical assistance from:
GERMAN DEVELOPMENT SERVICE

August 2000

Dear Reader,

I would like to comment this handout, because otherwise you might get a little confused while studying it.

The most important thing to know is, that this handout is developed for a **non–formal** Training Center. The participating government officials and the involved companies were not interested in long–term courses. So, I had to respect the wish of my project partners for a course with this length and was limited on the most important subjects.

One or two of the modules are still under construction. Sorry for this.

DED – Development Worker

GENERAL SURVEY

TARGET PARTICIPANTS

• High school graduates and skilled workers with at least 6 to 12 month experience in other welding processes

• Supervisors and leadsmen

LENGTH OF COURSE

40 hours

OBJECTIVES

At the end of the course, the participants should be able to:

- know the differences between the most common welding technologies and the GMAW (MIG) welding process
- learn the different shielding gases and the common types of wire and their costs
- identify the most important parts of a MIG/MAG welding machine
- know how to change the machine parameters and the working and consumable parts of the machine
- make use of the most common edge preparations and the different weld joint designs
- know how to weld mild steel with different techniques, positions and joints
- identify welding defects and know how to correct them
- make use of different grinding machines
- know and use the proper safety procedures and equipment

COURSE OUTLINE

THEORY (33 %)	HANDS–ON TRAINING (67 %)	METHODOLOGY
• The most common welding processes • GMAW – welding process • GMAW machines and equipment • Shielded gases • Types of electrode wires • Edge preparations • Joint and groove design • Welding positions • Welding defects • Grinding machines • Quality and cost consciousness • Safety	• Handling a GMAW welding machine and the necessary equipment • Daily check and maintenance • Welding of mild steel with different techniques, positions and joints • Edge preparations (groove design) • Weld joint design • Use bench and handgrinders • Safety	• Lectures/Discussions • Practical Sessions • Self experiences • Case studies • Video tapes

Time Frame Plan of GMAW (MIG) Welding
(Duration 40 hours)

Topic	Theory	? Methodology ? Resources Needed	Hours	Hands–On Training (Practical Sessions)	Hours	Total Hours
Orientation	• Policies of XXXXXXX • Introducing of saff	? Lecture ? XXXXXX manual “General Policies and Procedures“	0.5	„Familiarization Tour“ to the Workshop and the Office–Building	0.5	1.0 (1.0)
Determine previous knowledge on welding	Previous knowledge test	? Test ? Previous knowledge test sheet	0.5	/	/	0.5 (1.5)
The most common welding technologies	Definition, advantages and disadvantages of Arc, Gas, TIG and GMAW welding technologies	? Lecture/Discussion ? Course handout	1.0	/	/	1.0 (2.5)
Orientation of GMAW welding machine	• The parts of a MIG/MAG welding machine • Parameter setting	? Lecture ? Course handout	1.0	• Show the important parts at the machine • Demonstration how to change the parameters at the machine	1.0	2.0 (4.5)
Orientation on consumable materials	Wire and protective gases	? Lecture ? Course handout	0.5	/	/	0.5 (5.0)
Maintenance of MIG/MIG welding machines	Check and maintain the MIG/MAG welding machine on a regular basis for a	? Lecture/Discussion ? Course handout	0.5	**Check:** contents of cylinder, supply of wire, electrical contacts	2.0	2.5 (7.5)

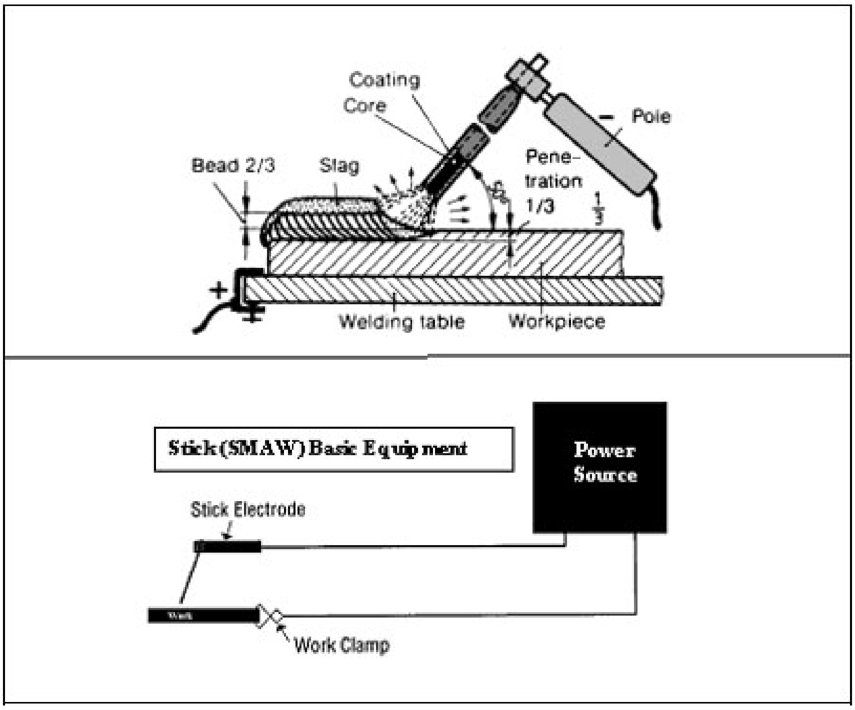
	trouble free working process			**Change:** Fuse, wire, feed roll, nozzle, contact tip **Clean:** Nozzle, contact tip		
Discussion of the GMAW welding process in general	• Machine circuit • Current, Frequency, Phases • Modes of Transfer	? Lecture ? Course handout ? Video tape	1.0	/	/	1.0 (8.5)
Discussion and application of the joint and groove design	**Basic joint designs:** Butt joint, Corner joint, T joint, Lap joint, Edge joint **Basic groove design:** Square, Square with root opening, Single V, Double V, Fillet T	? Lecture ? Course handout ? samples of work pieces	1.0	Prepare workpieces with different joints and different grooves	4.0	5.0 (13.5)
Discussion and application of welding techniques and Torch manipulations	Backhand, Forehand, Flat and Vertical position, Work angles, Travel speed, Electrode extension (Stickout)	? Lecture ? Course handout	1.0	Basic welding exercises	15.0	16.0 (29.5)
Discussion and application of weld defects	Incomplete penetration, Incomplete Fusion, Undercut, Cracking, Porosity, Spatter	? Lecture/Discussion ? Course handout ? samples of work pieces	2.0	Analyze the welding defects and correct them during the welding exercises	2.5	4.5 (34.0)
Orientation on quality and cost consciousness	Examples of the importance of quality, punctuality, work speed, etc. (time is money)	? Lecture/Discussion ? Course handout	1.0	/	/	1.0 (35.0)
Safety	Electrical Shock, Arc Rays, Fumes and Gases, Clothing, Eye Protection, Environment, Safe handling of Gas Cylinders, Safe handling of hand−grinder and bench grinder	? Lecture/Discussion ? Course handout ? samples of safety equipment	1.0	Discussion and hands on how to use safety equipment directly at the workplace	1.0	2.0 (37.0)
Final Test	Theoretical test Trade test	? Test ? Final test sheet	1.0	Weld a workpiece with several layers	2.0	3.0 (40.0)

Total			**13.0**		**27.0**	**40.0**

1. SHORT DISCRIPTION OF THE MOST COMMON WELDING PROCESSES

1.1 SMAW (Shielded Metal Arc Welding)

SMAW is one of the oldest, simplest and most versatile joining processes. The electric arc is generated by touching the tip of a coated electrode against the workpiece. The electrodes are in the shape of a thin long stick ***(stick welding).*** The heat generated, melts a portion of the tip of the electrode, its coating, and the base metal in the immediate area of the arc. A weld will be formed the molten metal (a mixture of the workpiece and the electrode metal) and substances from the coating of the electrode, solidifies in the weld area. The electrode coating deoxidizes and provides a shielding gas in the weld area to protect it from oxygen and nitrogen in the environment. Electrodes are available for welding most carbon, low alloy and stainless steels, some non−ferrous metals, and a wide range of maintenance and repair applications.



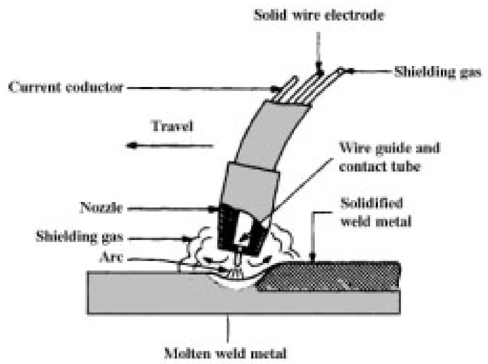
Operation:	Manuel
Energy source:	AC or DC usually between 50 A and 400 A
Welding positions:	All
Cost of equipment:	Low
Advantages:	Portable and flexible, low cost of equipment
Field of application:	General construction, shipbuilding, pipelines, maintenance, workpieces from 3−19 mm thickness – with multiple techniques easily to extend.

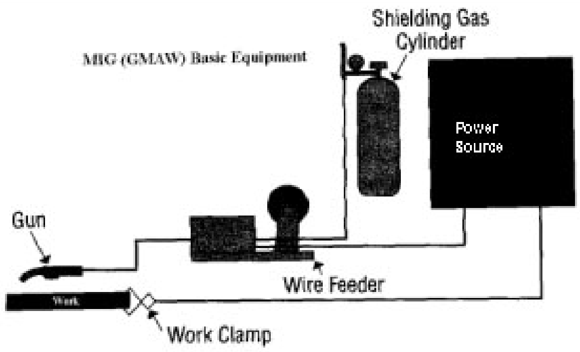
1.2 GMAW (Gas Metal Arc Welding)

GMAW was developed in the late 1940's and is also called ***MIG/MAG Welding***. Since then it unfolded into becoming a major element in industry today. It is suitable for welding a variety of ferrous and nonferrous metals.

The arc continuously melts the wire as it is fed in the weld puddle. The weld area is shielded by a flow of gas such as argon, helium, carbon dioxide, or gas mixtures. The consumable bare wire is fed automatically through a nozzle into the weld area. Metal can be transferred into the weld–bead in three ways: Spray, Globular and ***Short circuiting***. Each way has its own advantages and disadvantages.

The process is rapid, versatile, economical and can easily be automated (continuos welding without electrode changing).





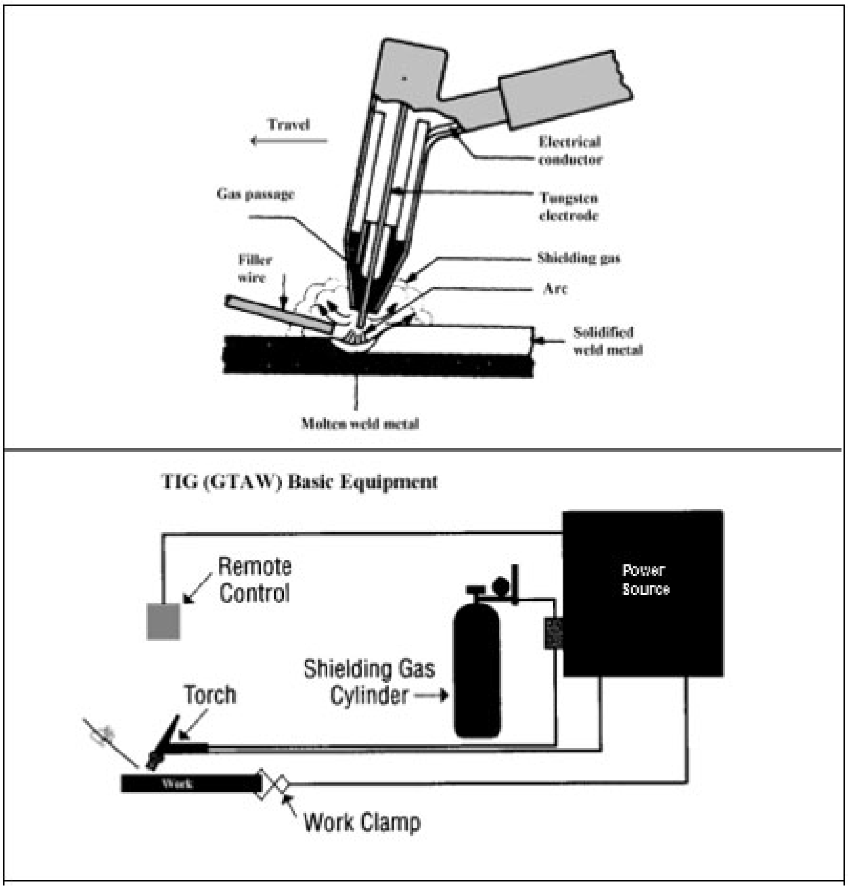
Operation:	Semiautomatic (Movement of Gun controlled by hand) or automatic
Energy source:	DC
Welding positions:	All
Cost of equipment:	Low to high
Advantages:	Most metals weldable, high welding productivity, excellent weld quality, minimal distortion.
Field of application:	General construction, general metal fabrication, car body, workpieces from 0.75 mm and 12 mm thickness – with multiple techniques easily to extend.

1.3 GTAW (Gas Tungsten Arc Welding)

GTAW also known as ***TIG welding*** *(Tungsten Inert Gas).* The filler metal is supplied from a filler wire and is similar to the metals to be welded. The tungsten electrode is not consumed in this operation and the shielding gas is usually argon or helium or a mixture of it. Welding with GTAW can also be done without filler metals, as in welding close–fit joints.

GTAW is used for a wide variety of metals and applications, particular aluminum, copper, brass, magnesium, titanium and high alloy metals. It is especially suited for thin metals. In general AC power supply is preferred for aluminum and magnesium because the cleaning action of AC removes oxides and improves weld quality. DC power supply is also possible.

The cost of the inert gas makes this process more expensive than SMAW, but it provides welds with very high quality and surface finish.



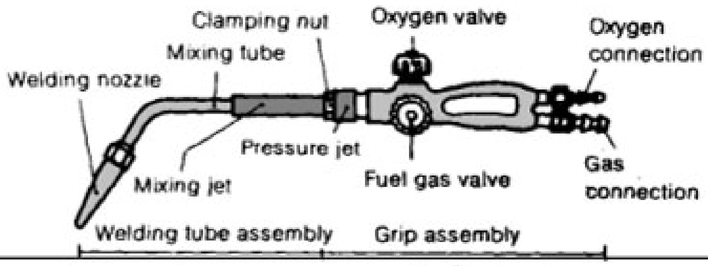
Operation:	Manual or automatic
Energy source:	AC/DC
Welding positions:	All
Cost of equipment:	Medium
Advantages:	Most metals weldable, high quality
Field of application:	Vessel, tank or boiler fabrication; tool or die repair; aluminium casting; pressure valves or regulators; pipe fittings; bicycle frames; airplanes

1.4 Oxy−Acetylene welding

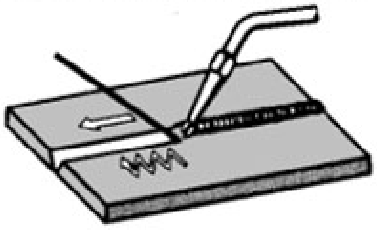
Oxy−Acetylene welding is developed in the 1900s and is the most common ***gas welding*** process. It uses acetylene fuel. The proportions of oxygen and acetylene are an important factor. At a ratio of 1:1, the burning gases get a *neutral* flame. If the supply of oxygen is lower it becomes a *reducing* flame. With a greater oxygen supply it becomes an *oxidizing* flame.

Filler metals are used to bring additional material to the weld zone during welding. They are available as rods or wire, coated and uncoated, and are made of metals compatible with those to be welded. Oxyacetylene welding can be used with most ferrous and nonferrous metals for any thickness of workpieces, but the relatively low heat input limits the process economically to less than 6 mm. A variety of joints can be produced by this method. It is portable, versatile and economic for low quantity and simple work.

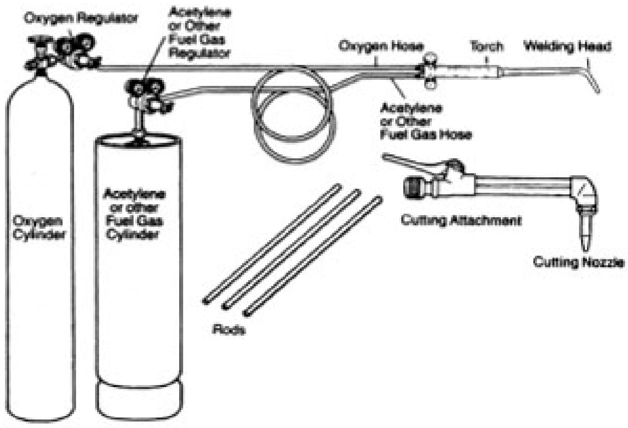
Welding torch



Leftward welding



Basic equipment



Operation:	Manual
Energy source:	Acetylene and Oxygen
Welding positions:	All
Cost of equipment:	Low
Advantages:	Low cost of equipment, portable and flexible, most ferrous and nonferrous metals weldable
Field of application:	Maintenance, tube−welding, car body repair

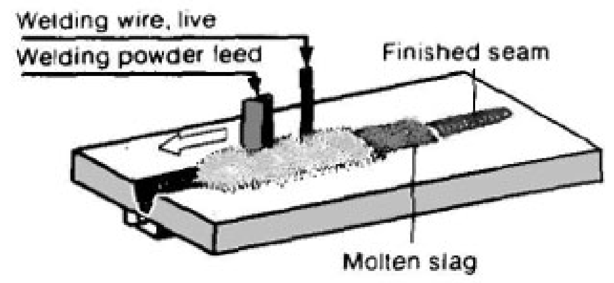
1.5 SAW (Submerged Arc Welding)

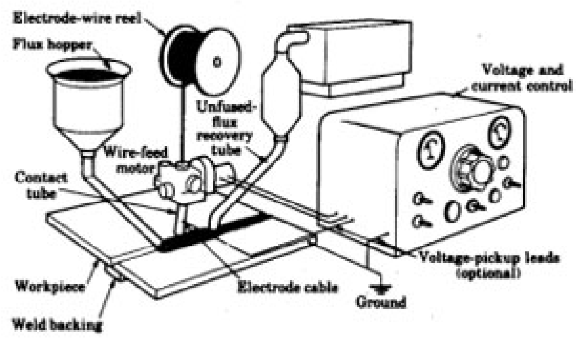
SAW, developed in the 1940s, is one of the most important automatic welding processes. The arc and the whole welding zone are covered by a layer of powder. The complete cover of the molten metal prevents sparks, spatter, intensive ultraviolet radiation and fumes. The flux, which is part of the powder, acts as a thermal insulator, allowing deep penetration of heat into the workpiece.

The consumable electrode is a coil of bare round wire (1.5 – 10 mm diameter) and is fed automatically through a tube (welding gun).

Because the powder is fed by gravity, the SAW process is limited to weld in a flat or horizontal position. Circular welds can be made on pipes, provided that they are rotated during welding. The unfused powder can be recovered, treated, and refused.

SAW is used to weld a variety of carbon and alloy steel and stainless steel sheet or plate with a high speed and productivity. The quality of weld is very high. Typical applications are thick plate welding for shipbuilding and pressure vessels.





Operation:	Automatic
Energy source:	AC/DC
Welding positions:	Flat and horizontal
Cost of equipment:	Medium
Advantages:	High deposition rate, high welding productivity, superior quality weldments
Field of application:	Thick plate welding for shipbuilding and pressure vessels

2. FUNDAMENTALS

2.1 History of GMAW

Gas Metal Arc Welding (GMAW) is an arc welding process that joins metals. It does this by heating the metals with an electric arc. The arc is between a continuous, consumable electrode wire and the workpiece. The arc is shielded from contaminants in the atmosphere by a shielding gas.

GMAW had its beginning in the late 1940's. It was developed to speed up welding that was being done by the Gas Tungsten Arc Welding (GTAW) process. GTAW is also an arc welding process shielded by shielding gas, but GTAW uses a nonconsumable tungsten electrode. The filler rod for GTAW is generally added manually **at a much slower rate**. **GMAW was thus developed to make welding a faster, more profitable process.**

GMAW developed when GTAW was thought to be too slow a process to weld thick sections of aluminum. Whereas GTAW worked very well on thin gauges (literally melting the metals together without adding filler wire), GMAW became much more efficient and profitable for welding thicker materials. This became especially helpful during the years of World War II.

During its early days, Gas Metal Arc Welding was generally done with small electrode wires, high heat, and shielding gases that were inert (nonreactive). Because an inert gas was used, the term Metal Inert Gas, or **MIG** welding, was used to refer to this process. This term is still a very common reference for the welding process, even though technically incorrect. The development over the years of the use of reactive shielding gases (Metal Active Gas – **MAG** welding) gave rise to the term Gas Metal Arc Welding, or GMAW.

Following WW II, the peacetime economy saw an increase of the economical Gas Metal Arc Welding process. In addition to being more profitable on heavy aluminum weldments, GMAW was refined to produce quality weldments on other materials and thicknesses, both thin and thick. Thus, the GMAW process unfolded into becoming a **major element in industry today**.

2.2 Types of GMAW

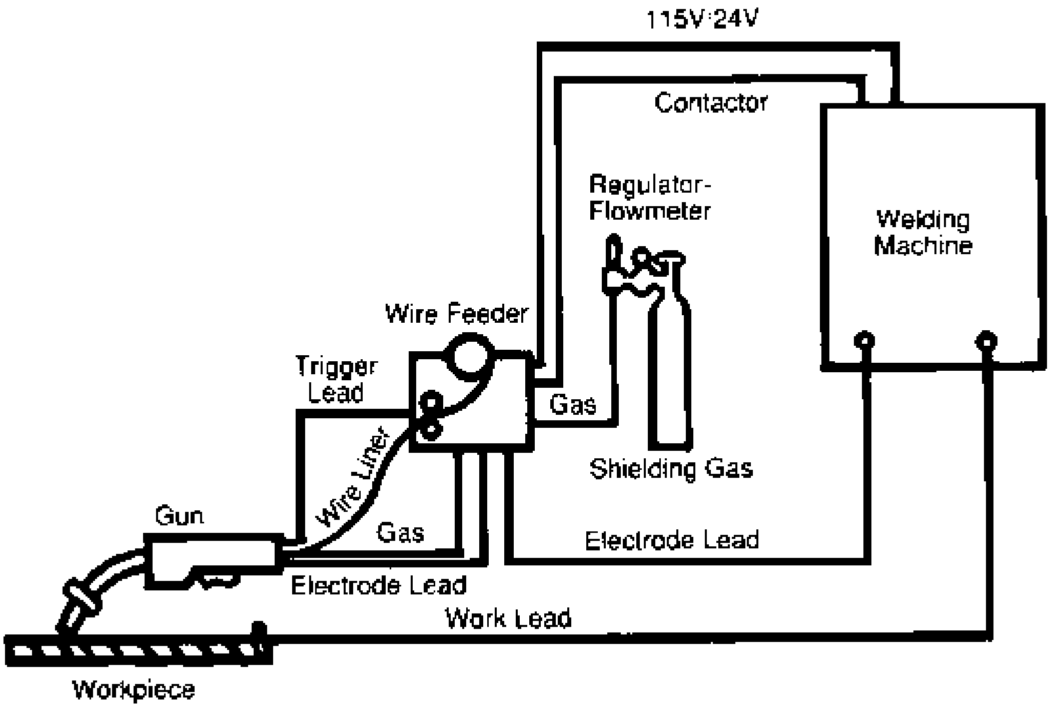
Gas Metal Arc Welding can be done in basically three different ways. **Semiautomatic** welding means that the equipment controls only the electrode wire feeding. The movement of the welding gun is controlled by hand. Thus, semiautomatic welding is sometimes called handheld welding. **Machine welding** uses a gun that is connected to a manipulator of some kind (not hand held). An operator has to constantly set and adjust controls that move the manipulator. **Automatic welding** uses equipment which welds without the constant adjusting of controls by a welder or operator. On some equipment, automatic sensing devices control the correct gun alignment in a weld joint.

2.3 GMAW Circuit

This is the basic equipment used for a typical GMAW, semiautomatic setup. Included are:

- A welding machine which provides welding power
- A wire feeder which controls the supply of wire to the gun
- A supply of electrode wire
- A welding gun, which directs the electrode wire into the joint
- A shielding gas cylinder, which provides a supply of shielding gas to the arc area.

The reason for the term "circuit" is that there is an electrical circuit from the welding machine through the electrode lead to the wire feeder, from the wire feeder to the gun via an electrode lead, through the gun to the wire, then to the arc, through the arc to the workpiece, and back to the welding machine via the work lead.



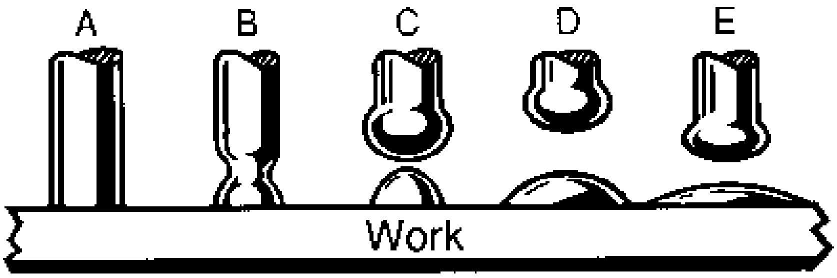
2.4 Modes of GMAW Transfer

2.4.1 Short Circuit Transfer

The short circuit transfer gets its name from the welding wire actually "short circuiting" (touching) the base metal many times per second. When the welding gun trigger is pressed, the electrode wire feeds continuously from the wire feeder, through the gun, and to the arc, short circuiting to the base metal.

In the course of welding, this cycle can repeat itself between 20 and as much as 250 times per second.

An average welding condition, however, would average between 90 and 150 short circuits per second. The number of short circuits per second will depend upon such things as slope and inductance settings, the size wire that is being used, and the Wire Feed Speed (WFS) that is set on the wire feeder. Naturally, the faster the wire feed speed, the more short circuits per second.



As you can see in the picture above, in **A,** the wire has come out of the gun and touched or "short circuited" the base metal. There is no arc, and current is flowing through the electrode wire and base metal.

In **B**, the heat of the current flow is causing a magnetic field to envelope the wire. The properties of the wire are having difficulty supporting all the current flowing through the wire. Thus, resistance builds up in the wire, it gets hot, and begins to lose strength, allowing the magnetic field to squeeze it.

In **C** the wire has begun to separate from the weld puddle. A small portion of electrode wire is deposited, which becomes part of the weld pool or puddle.

At point **D,** the heat of the arc is more powerful than the wire feedspeed. Eventhough the wire is feeding at the same rate throughout this cycle, the heat of the arc in **D** is changing the shape of the weld puddle and the end of the elecectrode. The heat of the arc is "wetting out" the puddle, and also widening out the tip of the electrode wire.

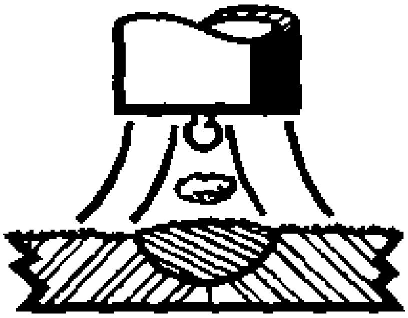
At **E**, the wire feed speed has overcome the heat of the arc, and the wire approaches the weld puddle again. Notice how the weld puddle has flattened out while the arc is "on".

With short circuit transfer, wire feed speeds, voltages, and deposition rates are usually lower than with other types of metal transfer. Because of this, short circuit transfer is a very versatile transfer, allowing the welder weld on thin or thick metals, and in all positions. This is due to using small diameter electrode wires for short circuit transfer, as well as relatively low voltage and amperage and wire feed speed values. This produces a small weld puddle which solidifies quickly, making short circuiting a very versatile process.

Wire diameter sizes for short circuiting transfer include.020",.023",.025",.030",.035", and.045".

2.4.2 Globular Transfer

With a globular transfer, the electrode wire only touches the base metal when welding begins. After that, globs of wire are expelled from the wire to the arc, often of larger size diameter than the unmelted electrode wire.



Globular

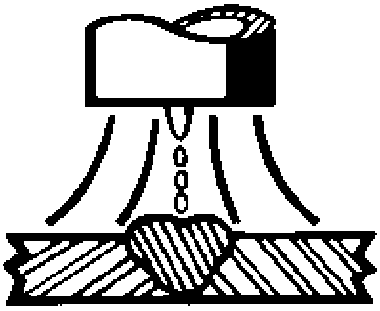
A globular transfer can result when using certain shielding gases. Also, a globular transfer can result when welding parameters such as voltage, amperage, and wire feed speed are somewhat higher than the settings for short circuit transfer.

Globular transfer can, in many cases, yield more spatters. Since spatter is waste, it is not a desirable side effect of globular transfer.

However, one popular use of globular transfer is a mild steel electrode wire and C02 shielding gas. This combination yields good penetration, and the C02 shielding gas is less expensive than many mixed gases.

2.4.3 Spray Arc Transfer

A spray arc transfer "sprays" a stream of tiny molten droplets across the arc, from the electrode wire to the base metal. These molten droplets are usually smaller than the diameter of the unmelted electrode wire. The arc is said to be "on" all of the time, once an arc is established.



Spray

The spray arc transfer uses relatively high voltage, wire feed speed and amperage values, compared to short circuit transfer. Because of the high voltage, wire feed speed, and amperage, there is a resulting high current density. The high current density produces high metal deposition rates. The high degree of heat in the spray arc weld puddle makes for a larger weld puddle that is more fluid than the weld puddle for short circuit transfer. Because of this heat and the size of the weld puddle, spray arc transfer is somewhat limited in welding position. Welding steel base metal with spray arc transfer is usually done in the flat position, and the horizontal position. Horizontal position spray arc welds are done only on lap and T−fillet welds.

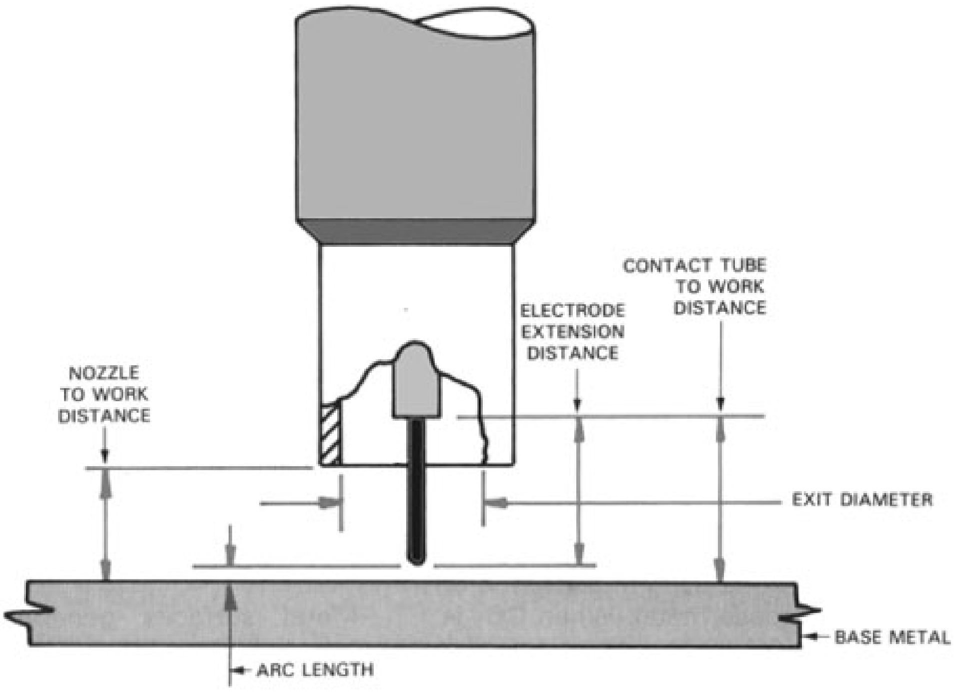
Because of the higher heat input, spray arc transfer is normally used on thicker metals. The high heat input could cause excessive melt−through on thinner metals.

To achieve a true spray transfer, an argon−rich shielding gas must be used. Usually a gas mixture of over 90% argon is used, with the remainder being a gas which gives special metal transfer characteristics, such as oxygen or CO2.

2.5 Welding Torch – Nozzle to Work Distance

The electrode extension is the amount the end of the electrode wire sticks out beyond the end of the contact tube. This distance is sometimes called as "**stickout**".

A good extension for short circuit transfer is about 6−12 mm. A to long stickout may cause extensive spatter.

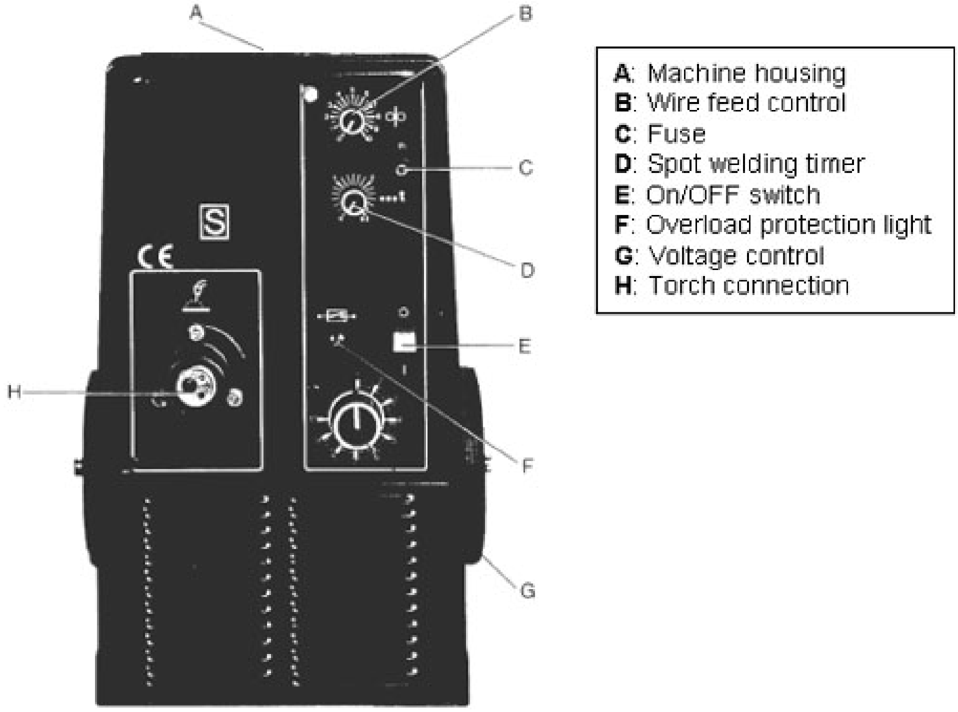


3. GMAW EQUIPMENT AND CONSUMABLES

3.1 Welding machine

With the many types of welding machines available, certain considerations must me made in order to fit the right machine to the job:

- Mode of transfer needed? (Short circuit, Globular Transfer, Spray Arc Transfer)
- Output needed? (Voltage and Amperage)
- Duty cycle needed? (How often must the machine cool down?)
- Multi−process capability needed? (Changeable for constant voltage and constant amperage)
- Remote control needed? (Voltage can be adjusted some distance away from the machine)
- Portability needed?
- Primary power available? (115V, 230V, 380V)



"MILLER" Mod. 300 A – "all–in–one" machine with a built in wire feeder

A manual (non water cooled) welding station is simple to install. Because arc travel is performed by the welder, only a few major elements are necessary:

- Power supply
- Welding control and wire feed motor
- Welding gun
- Welding wire
- Shielded gas

3.2 Power supply

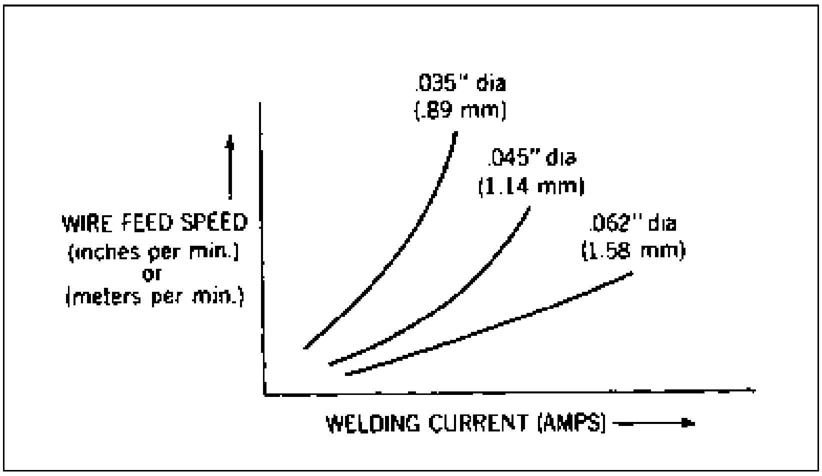
Almost all GMAW welding is done with ***direct current*** *(DC)* ***reverse polarity***. The primary source is normally either 230 V or 460 V AC current input power, which is changed by a rectifier unit to secondary circuit DC. The power source should be a ***constant voltage*** welding machine *(CV)*. This contrasts with SMAW welding which use ***constant current*** *(CC)* power supplies.

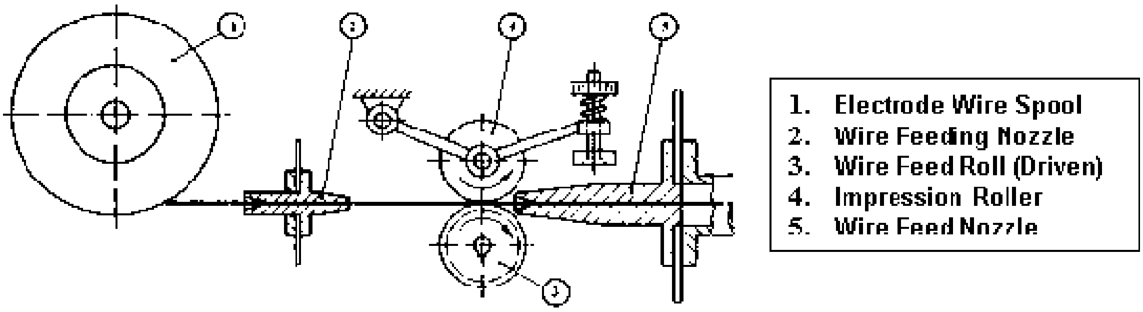
A GMAW welding power supply provides a relatively constant voltage to the arc during welding. This voltage determines the arc length dependent to the current (amperage) being used. The welding current output depends on the wire–feed–speed, while the voltage output is adjusted by a voltage regulator.

When there is a sudden change in wire feed speed, or a momentary change in arc length, the power supply abruptly increases or decreases the current depending on the arc length change.

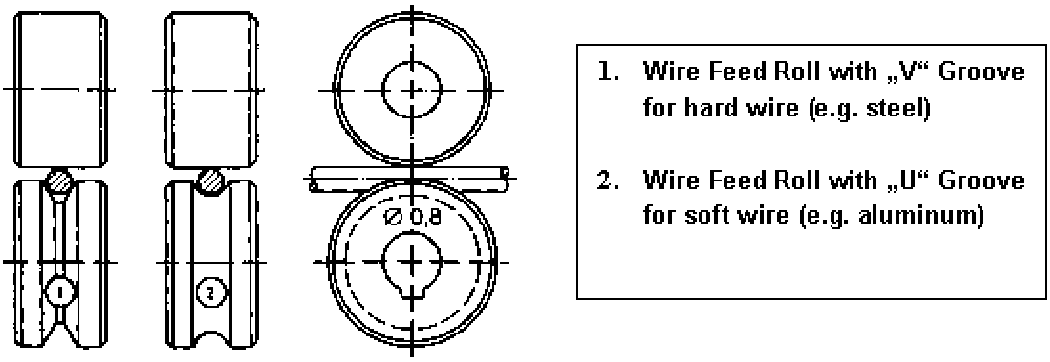
3.3 Welding control and wire feed motor

For GMAW machines with constant voltage, current (amperage) is controlled by wire feed speed. Wire feed speed (WFS) refers to the rate at which the continuous electrode wire is fed out of the gun into the weld bead. The rate is usually measured in meters per minute. If wire speed is increased, amperage is also increased and inverse the same.





Wire Feed Device



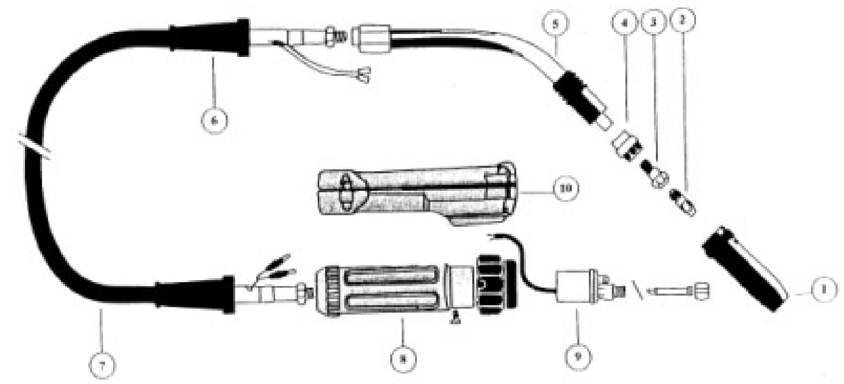
Wire Feed Drive Roll Kits

The wire feed roll should be selected in accordance with the wire diameter. If not, there will be a disturbing in the wire feeding.

3.4 GMAW Welding Gun (Example of an uncooled semiautomatic gun)

As compared to a SMAW electrode holder, the GMAW gun is more expensive and complex. This is because there is more required of it than just carrying electrical power to the electrode wire:

- A weld power cable connection brings electrical energy to the gun´s contact tube area.
- The gun guides shielding gas into the weld zone.
- The gun has also a connection for getting the electrode wire from a drive rolls, to the contact tube inside the gas nozzle.
- A trigger switch connection allows to control weld starting and stopping



1: Nozzle – Because of the intense heat near the arc area nozzles are often made of copper. There are different types of nozzles for different welding processes available.

2: Contact Tube (or Tip) – is made of copper and is used to bring welding power to the wire as well as direct the wire toward the workpiece. The used size (e.g. 0.8 mm) must fit to the used wire (0.8 mm).

3: Contact Tupe Holder

4: Head Insulator/Gass Diffusor

5: „Swan Neck“ 50°

6: Cable Support

7: Complete Power Cable

8: Complete Adaptor Support

9: Central Adaptor Block

10: Complete Handle

3.5 Electrode wire

Compared to other electrodes, such as those used for SMAW, the electrode wire for GMAW is small in size. Also the current used for GMAW wires can be quite high. This leads to two important features of GMAW.

- The **deposition rates** are good. Melt rates are high which leads to good kilo per hour of weld metal deposition

- The GMAW process can be referred to as a **"low hydrogen" process**. The bare electrode wire has less change of attracting moisture than does a coated SMAW electrode. This helps avoid porosity problems when the correct GMAW electrode wire and shielding gas are used.

Also there is no industry–wide specification, most wires conform to the **A**merican **W**elding **S**ociety Standards. AWS sets specifications for acceptable standards on the manufacturing of electrode wires.

- **Sizes and dimensions of spool** (helps manufacturers design equipment that can conform to the wire–holding devices.

- **Winding of the wire** (The wire should be smoothly wound on the wire–holding device).

- **Continuation of the wire** (It is important for the wire–holding device to contain wire that is one, continuos length of electrode wire. No starts and endings are allowed).

- **Source of wire** (The whole spool of wire should be finished with the same „Batch“ of raw material).

- **Identification** (The wire should be identified by: Manufacture name, AWS classification, wire size and the net weight of wire on a spool).

There are so many kinds of steels, aluminum's etc. This is the reason for the classification of welding wire. For example: **ER70S–2**:

The letter "**E**" stands for Electrode. The "**R**" stands for Rod, meaning the same wire may be used for filler rod for a GTAW application. The number "**70**" indicates the required minimum as–welded tensile strength, measured in pounds per square inch (psi). The "**S**" refers to a solid electrode wire. The "**2**" refers to a particular degree of manufactured chemical percentage within the wire´s composition.

- **Temper** (The degree of hardness and strengths (temper) in an electrode wire can affect wire feeding)

The welder may ask: "How do I know which electrode wire to use?"

In many cases, the welder will not select the electrode wire and shielding gas used. They may be dictated by the written welding specifications for the job, or by plant supervisor or welding engineer. It is nevertheless important to know these types of electrodes to obtain a well–rounded welding knowledge.

There are a few basic points to consider in selecting an electrode wire.

- When selecting a wire, it is very important that the ***mechanical properties*** of the base metal be known. The tensile strength and ductility of a particular steel (or other metal) are important when making an electrode wire selection.

- The chemical makeup of the base metal will have an effect on wire selection. This can be particularly true if the metal is a low alloy or high alloy type base metal.

High alloy steels have high amounts of alloying elements added to the metal to give it a particular property. Stainless steels are a good example of high alloy steels, due to their high chromium (Cr) or nickel (Ni) contents.

Mild steels generally do not have all of these "extra" alloys added to them. Mild steels make up the bulk of metals welded together.

For example, most bare continuous steel electrode wires have a low carbon content. This helps to avoid hardness and cracking problems that would result from high carbon content electrode wires.

Care and storage of electrode wires

If electrode wires (and other consumables) are not handled and stored properly, the welding conditions may be bad before an arc is struck.

Any consumable should be kept in its package until it is needed. This includes wires, drive rolls, cable liners, contact tubes and other items. If left out in the open, these items can become dirty and cause poor wire feeding when used.

It is extremely important to keep the electrode wire clean and dry in order to produce good welds. Using common sense will be a welder's best bet when handling and storing electrode wires. The following tips will help keep the wire clean.

- When storing the wire before use, it is absolute necessary that the wire be **kept dry**. Moisture can cause rusty wire, which leads to poor feeding. It can produce welds that contain defects such as porosity and other possible problems.

- If a spool of wire is partly used and not going used for a longer time, it may be helpful to store the wire in a package.

- The device clamps between the wire spool and the inlet guide should be free of dust and rust. Sometimes a simple device like a clothespin is used to clean the wire before it reaches the drive rolls or the gun.

- If the spool wire is old, dirty or rusty, remove some of the top layers of bad wire and see if cleaner wire is below.

3.6 The most common shielded gases and mixtures

Shielding gases for semiautomatic GMAW flow from the welding gun nozzle. They protect the melting electrode and weld zone from the surrounding atmosphere, which would contaminate the weld. Selecting the proper shielding gas can depend upon the metal being welded, the weld quality or metal properties desired, process performance and cost of the gas.

Argon

Argon is an inert gas (MIG−welding) which is used both singularly and in combination with other gases to achieve desired arc characteristics for the welding of both ferrous and non−ferrous metals. Almost all welding processes can use argon or mixtures of argon to achieve good weldability, mechanical properties, arc characteristics and productivity. Argon is used singularly on non−ferrous materials such as aluminum, nickel based alloys, copper alloys, and reactive metals which include zirconium, titanium, and tantalum. Argon provides excellent spray arc welding stability, penetration and bead shape on these materials. Some shortcircuiting arc welding of thin materials is also practiced. ***When using ferrous materials, argon is usually mixed with other gases such as oxygen, helium, hydrogen, carbon dioxide and/or nitrogen.***

The low ionization potential of argon creates an excellent current path and superior arc stability. Argon produces a constricted arc column at a high current density that causes the arc energy to be concentrated in a small area. The result is a deep penetration profile.

Carbon Dioxide

Pure carbon dioxide is not an inert gas (MAG −welding), because the heat of the arc breaks down the CO, into carbon monoxide and free oxygen. This oxygen will combine with elements transferring across the arc to form oxides which are released from the weld puddle in the form of slag and scale.

Carbon dioxide is widely used for the welding of steel. Its popularity is due to the common availability and quality weld performance as well as its low cost and simple installation. It should be mentioned that low cost per unit of gas does not automatically translate to lower cost per foot of weld and is greatly dependent on the welding application. Factors such as lower deposition efficiency for CO2, caused by spatter loss, influence the final weld cost.

The advantage of CO2, is fast welding speeds and deep penetration. The major drawbacks of CO2, are a harsh globular transfer and high weld spatter levels. The weld surface resulting from pure CO2, shielding is usually heavily oxidized. A welding wire having higher amounts of deoxidizing elements is sometimes needed to compensate for the reactive nature of the gas. Overall, good mechanical properties can be achieved with CO2,. ***Argon is often mixed with CO2, to off−set pure CO2, performance characteristics. If impact properties have to be maximized, a CO2, + argon mixture is recommended.***

Helium

Helium is an inert gas (MIG−welding) which is used on weld applications requiring higher heat input for, deeper penetration and higher travel speed. In GMAW it does not produce as stable an arc as argon. Compared to argon, helium has a higher thermal conductivity and voltage gradient and yields a broader and more shallow penetration pattern. Aluminum welding with pure helium does not give the cleaning action that pure argon experiences but is beneficial and sometimes recommended for welding thick aluminum. The helium arc column is wider than argon which reduces current density. The higher voltage gradient causes increased heat inputs over argon thus promoting higher puddle fluidity and subsequent bead wetting. This is an advantage when welding aluminum, magnesium and copper alloys.

Helium is often mixed with various percentages of argon to take advantage of the good characteristics of both gases. The argon improves arc stability and cleaning action, in the case of aluminum and magnesium, while the helium improves wetting and weld metal coalescence.

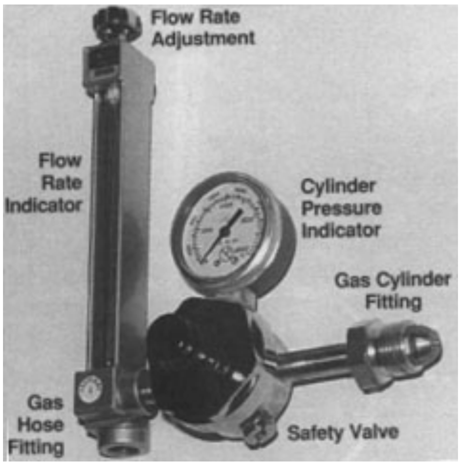
Common Mixtures

- Argon−CO2 – in different mixtures from 3 % CO2 up to 75 % CO2
- Argon−Oxygen – in different mixtures from 1 % O2 up to 25 % O2
- Argon−Helium – in different mixtures from 10 % He up to 90 % He

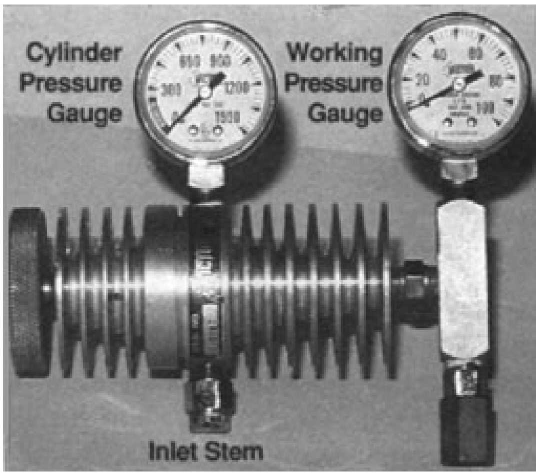
There are also mixtures with 3 or 4 different gases for special operations available.

Regulators – Flowmeters

A regulator–flowmeter is a device to deliver steady, preset flow of pressurized shielding gas to the welding area. A hose is usually connected between the regulator–flowmeter and a gas valve on the wire feeder. From the gas valve, a hose connection that is generally part of a gun assembly delivers shielding gas through the gun head tube and nozzle to the welding area.



Regulator and CFH Adjustment A common practice is to start with 12–15 **C**ubic **F**eet per **H**our



Regulator with 2 Gauges

4. JOINT AND GROOVE DESIGNS

4.1 Joint Design

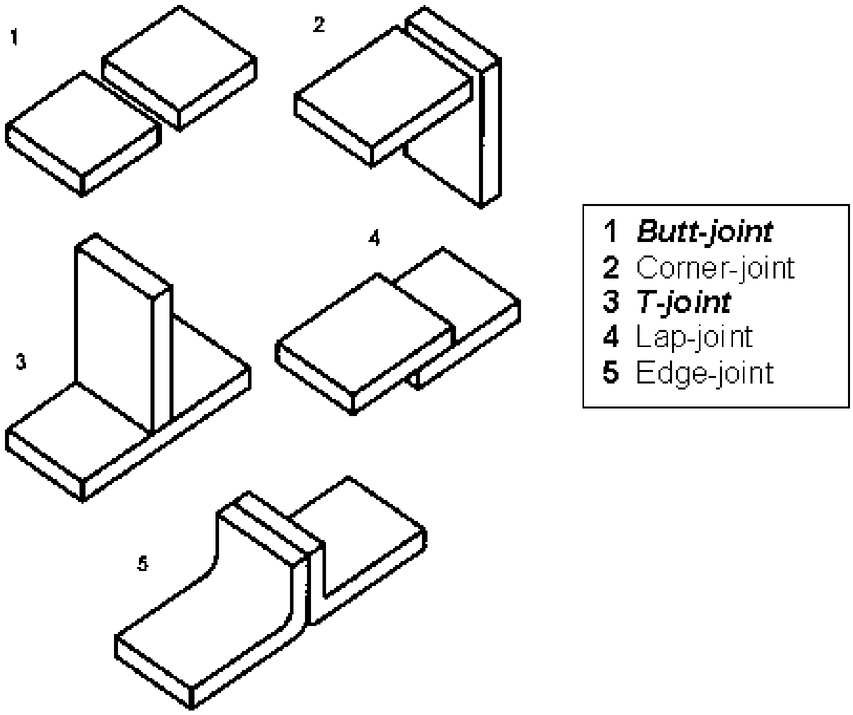
A *weld joint* is the term used for the location where two or more pieces of metal are to be, or have been, welded together. In order to obtain a good weld and economical use of filler metal (welding wire for GMAW), joint design must be considered in any type of weldment. This will depend upon several factors including material type, thickness, joint configuration, strength required, etc.

It is quite possible that a welder would have little to do with how a particular joint is designed.

However, a good welder should be familiar enough with these joint designs to carry out a welding job.

A proper joint design will provide the required strength that codes and specifications designate. The correct joint design will then need the highest quality weld made at the most economical cost. The joint design selected will, of course, dictate what type of weld is to be made.

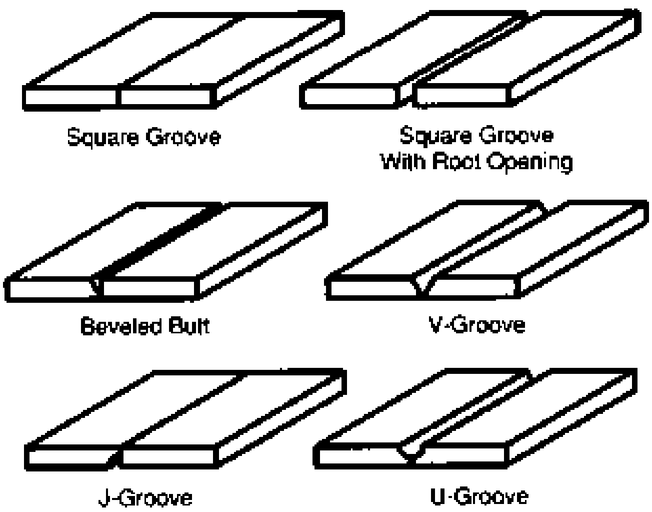
Of the five basic joint designs, the “**Butt**“ and “**T**“ are the most commonly welded.



A few considerations for joint design must be made that are particular for GMAW. Naturally the weld joint must be accessible to the GMAW gun, making it possible for proper gun movements. Weld joints also should not be too narrow, so as to restrict access of the gun nozzle. (In some cases, narrower gun nozzles will help.) Also, the nozzle−to−work distance cannot be too great in the weld joint so as to cause poor root penetration and poor shielding gas coverage.

4.1.1 Butt Joints

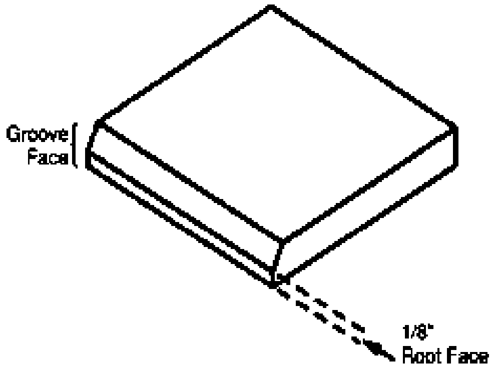
A butt joint occurs when the surfaces of the members to be welded are in the same plane with their edges meeting. Butt joints are often used to join such things as pressure vessels, boilers, tanks, plate, pipe, tubing or any application where a smooth weld face is called for. They generally require more welding skill than do some of the other joints. Butt joints have very good mechanical strength if properly made. They can be expensive joints to make, however, since many times some *joint preparation* must be done. Distortion and residual stresses can be problems with butt joints. Butt joints can be designed in various ways. The edges can be square, beveled, or grooved. Edges may be held tight together or a small gap known as a *root opening* may be left between the edges.



To keep the two separate, the picture below shows the difference between the *groove face* and the *root face*. In this example the root face is 1/8". The groove face means the surface of the metal in the groove including the root face. The main purpose of the various grooves and root openings is to allow proper penetration and depth of fusion.

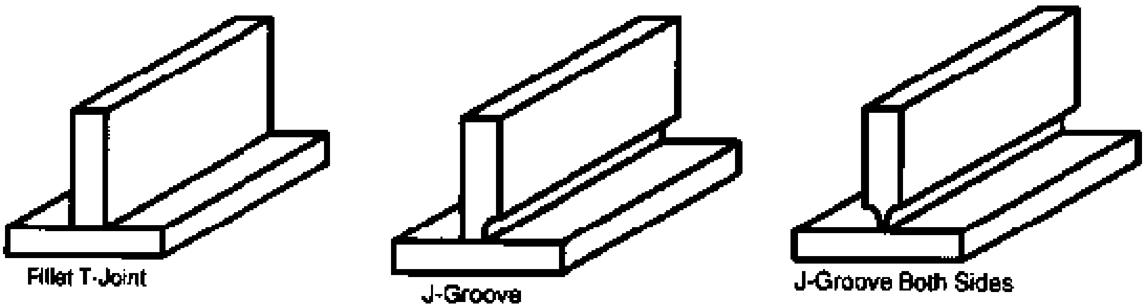
For example, if material thickness is less than approximately 1/8 inch (3,2 mm) thick, square edges can be used with a short circuiting process. (Aluminum would probably require a small root opening.) However, plate thickness 1/8 inch and greater generally require single or double V−grooves and root openings for proper penetration and depth of fusion. Joint preparation before welding will depend upon the joint design and the equipment available to do the edge preparation.

The oxy−fuel torch is often used to cut a bevel edge or square edges on steel plates.



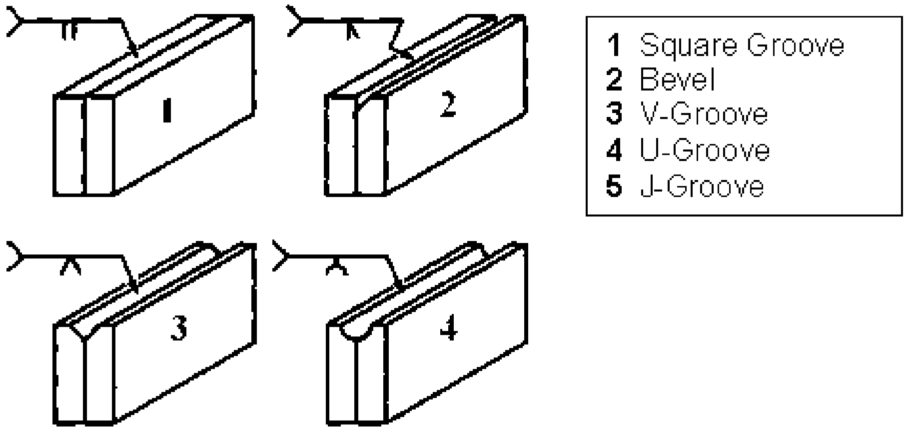
4.1.2 T−Joints

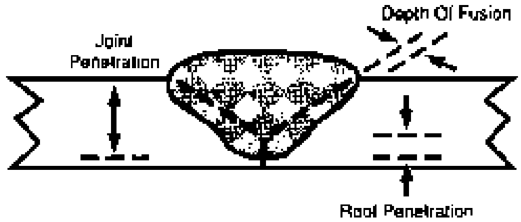
A T−joint occurs when the surfaces of two members come together at right angles (90 degrees) and take the shape of a **"T"**. On this particular type of joint, a fillet weld is usually made. T−joints offer good mechanical strength, especially when welded from both sides. They generally require little or no joint preparation and are easily welded when the correct parameters are used. The edges of the T−joint may be left square or they may be altered by cutting, machining or grinding.



4.1.3 Edge Joints

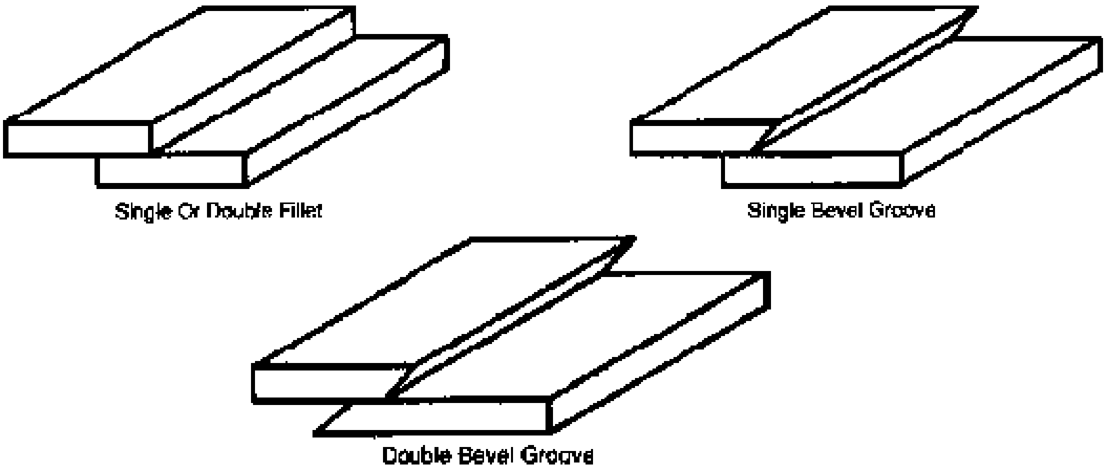
Edge joints are often used when the members to be welded will not be subjected to any great stresses. Edge joints are not recommended where impact or any other great stresses may occure to one or both of the welded members. An edge joint occurs where the edges of parallel or nearly parallel members meet and are joined by a weld. The main purpose of these grooves is to allow proper penetration or depth of fusion.





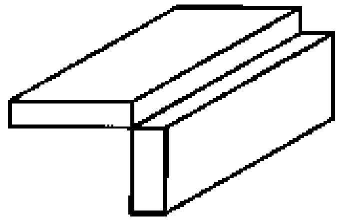
4.1.4 Lap Joints

Another joint design used in the welding industry is the lap joint. As can be seen in the picture below, lap joints occure when the surfaces of joined members overlap one another. A lap joint has good mechanical properties, especially when welded on both sides. The weld form used on a lap joint is generally a fillet weld. The degree of overlap of the members is generally determined by the thickness of plate. In other words, the thicker the plate, the more overlap is needed.

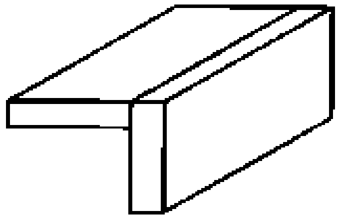


4.1.5 Corner Joints

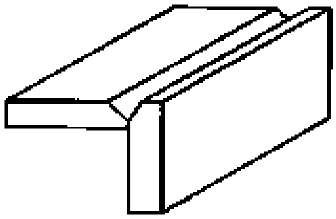
When members to be welded come together at weld is usually made about 90 degrees and take shape of an **"L"**, they are said to form a corner joint. These joints are quite easily assembled and require little if any joint preparation. After welding, the welds are generally finished, that is, ground smooth to present a smooth attractive appearance. When this is the case, all effort by the welder should be made to prevent roll over (weld material rolling onto one of the members), high spots, low spots and undercut. These problems can all mean more work since additional grinding time, re−welding and regrinding may be required. There are two main types of corner joints, open corner and closed corner. On lighter gauge material, it may J−Groove be necessary to increase travel speed somewhat, especially on open corner joints where excessive melt through is a possibility.



Open Corner



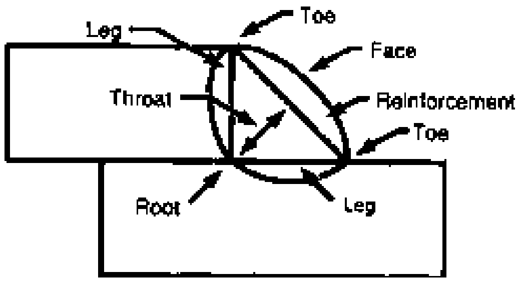
Closed Corner



V-Groove Corner

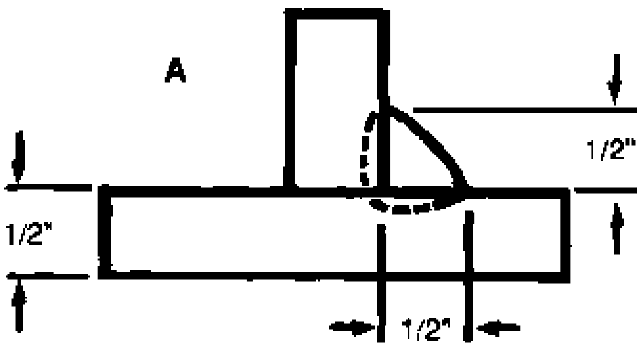
4.1.6 Fillet Welds

Fillet welds are approximately triangular in cross sectional shape and are made on members whose surfaces or edges are approximately 90 degrees to each other. Fillet welds can be as strong, or stronger than the base metal if the weld is the correct size and proper welding techniques are used. When discussing the size of the fillet weld, it is generally the length of the leg of the weld that is being referred to. The figure below shows a fillet weld and the terms associated with it. The general rule for fillet weld size is: the leg should be the same size as the thickness of the metals. If 1/2 inch thick plate is being welded, a 1/2 inch leg fillet is needed to properly join the members. The old saying, "if a little is good, a lot is better“, may be true in some cases **but not** with fillet welds.

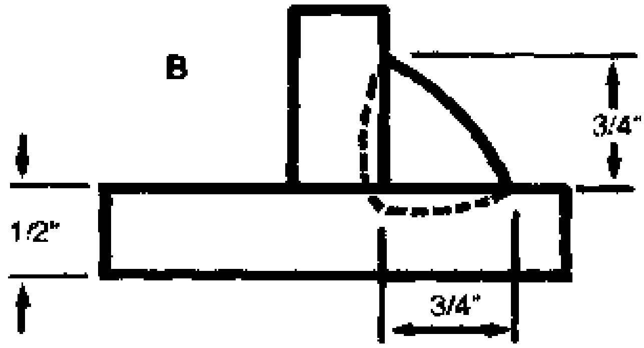


Fillet Weld Terms

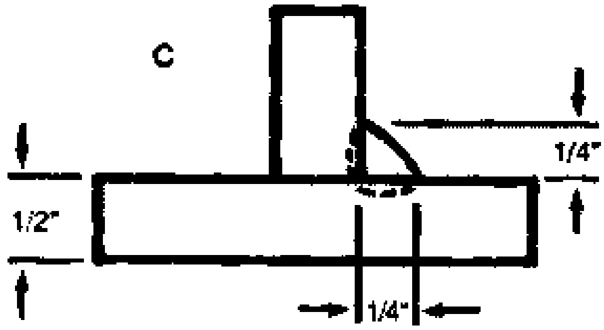
Consider again the 1/2 inch thick plate. If a lot of weld would be better, think of 3/4 inch legs on the fillet. This would result in what is termed overwelding. This wastes weld metal, the welder's time, causes more distortion and may even weaken the structure because of residual stress. The pictures below are showing correct and incorrect fillet welds.



A correctly fillet weld. Leg equals thickness of plate

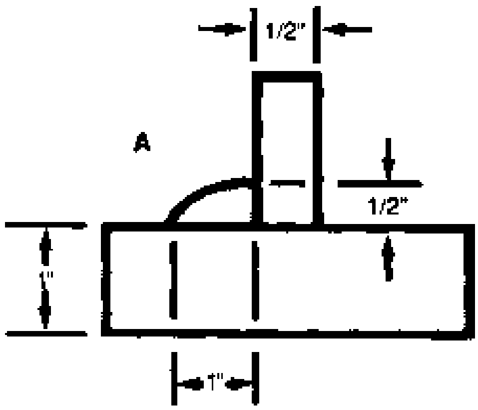


Over welded. Legs of weld too large for thickness of plate

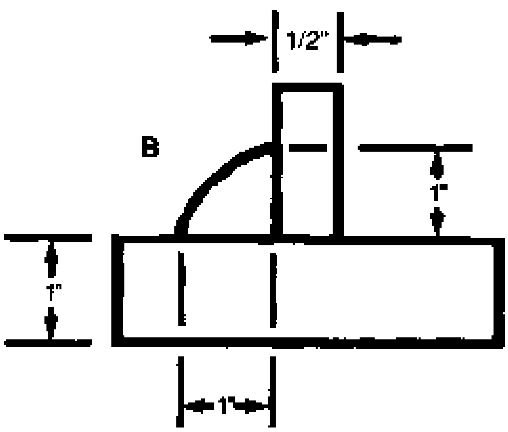


Under welded. Need larger legs on fillet

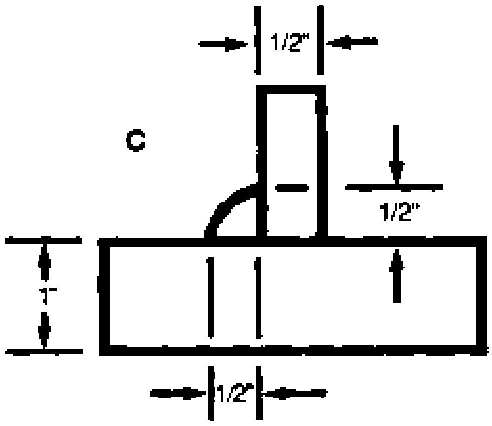
And consider another factor in correct fillet weld size – when metals of different thickness are to be joined. When welding a 1/2 inch thick plate onto a 1 inch thick plate in the form of a T–joint, the rule for fillet weld size is: Size of fillet weld leg should equal the thickness of the metal being welded. Since there are two different thickness, the best results will be obtained by making an unequal leg fillet weld. **A weldment is not stronger than its weakest point.**



Unequal leg fillet (joint failure)

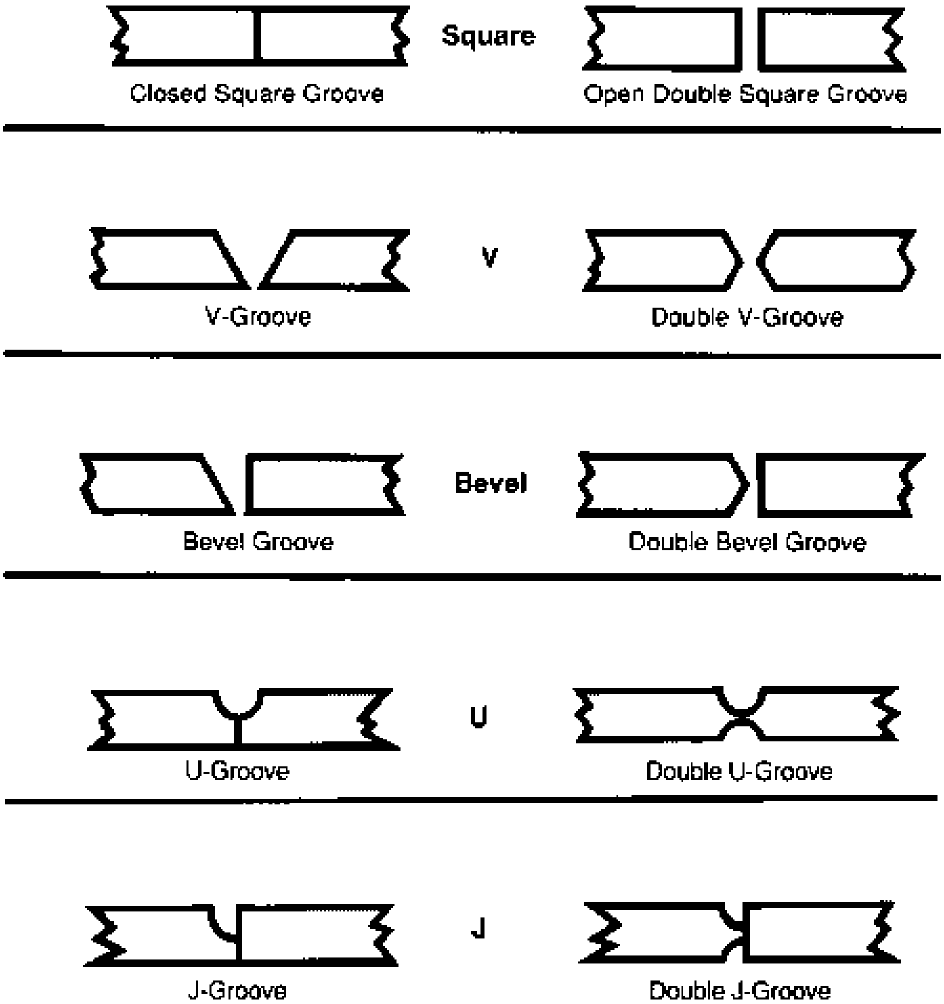


Equal leg 1" fillet (wasted weld metal, time and extra heat)



Equal leg 1/2" fillet (less time, less weld metal, less heat input. Just as strong as figure B

4.2 Groove Design



Common Groove Designs

4.2.1 Square−Groove

A square−groove weld can be made with either a closed or an open groove.

Usually if the base metal is thin (such as thin sheet metal gauge thicknesses), a square groove weld can be made. In the base metal thickness range of 1/8" to 1/4", it is good to weld both sides of an opensquare−groove− weld to provide proper penetration into the groove. Usually, open−square−groove−welds will not be made with groove openings of more than about 5/32". In some cases where welding is done from only one side of the joint, a temporary or permanent backup bar or strip may be used. This can ensure proper joint penetration, help avoid excessive melt through, or provide a flush backing to the weld.

4.2.2 V−Groove

Although they can require careful preparation, V−groove weld designs are quite popular. They can provide excellent weld quality if properly completed. V−groove weld designs may or may not use permanent or temporary backups, depending upon the joint design and type of joint penetration needed. Usually if backups are used, root openings can be somewhat wider.

V−groove welds are usually made on medium to thicker metals, and are used quite often for pipe welding.

The groove angle for a groove weld must be large enough for the welding gun to fit into the groove. This depends upon metal thickness, desired electrode extension and gun nozzle size. Usually V−groove welds are made on material over 1/8" to 1/4" in thickness. As the metal thickness increases, a root face can help provide good penetration.

The groove angle for GMAW groove welds **is usually smaller** than the Groove angles needed for SMAW. This can be a cost saver. As mentioned earlier, tapered nozzles and contact tubes are sometimes used to provide access into smaller grooves. A typical V−groove angle could be 60 degrees or even less, compared to 60 to 75 degrees for SMAW.

V−groove welds are often made on material up to about 5/8" thickness, while double V−groove welds are normally made on thicker materials up to roughly 2" in thickness. Double V−groove welds on thicker materials can use less deposited weld metal and limit distortion in the weld, especially if a small root face of about 1/8" is used on each member. Usually the weld passes on such a joint would be made alternating from one side of the joint to the other. This can help avoid distortion.

4.2.3 BEVEL−GROOVE

The bevel−groove welds also require preparation. But in this case only one member need be beveled. The single bevel−groove can be used on material up to about 5/8", while double bevel−grooves are used on thicker material up to about 1". In most cases, up to 1/8" root openings are used on single and double bevels.

4.2.4 U− AND J−GROOVES

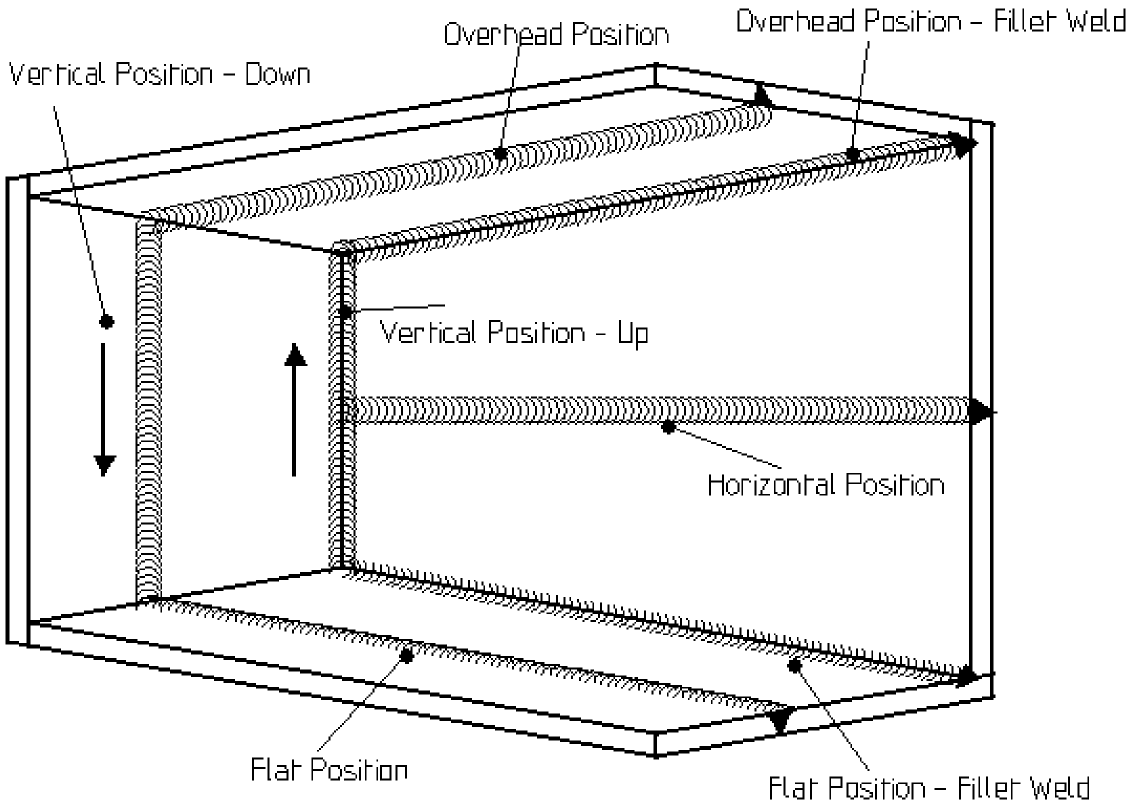
On thicker materials, U− or J−grooves can provide for good penetration. This is without using as much deposited weld metal as a V−groove or bevel−groove joint design. This is because with thicker materials, the U− and J−grooves can be used with a smaller groove angle and still maintain proper fusion. A normal groove angle for either a U or J−groove is about 20 to 25 degrees. This would also apply to the double U− and double J−grooves.

Usually no root openings are used for these grooves on thicker materials. Material thicknesses can range from 1/2" and thicker.

One disadvantage of U− and J−groove designs is the preparation of the base material. Special gauging or other preparation is needed for the J type design. V− or bevel−grooves are easier to prepare.

5. WELDING POSITION AND TORCH MANIPULATION

5.1 Overview of Welding Positions



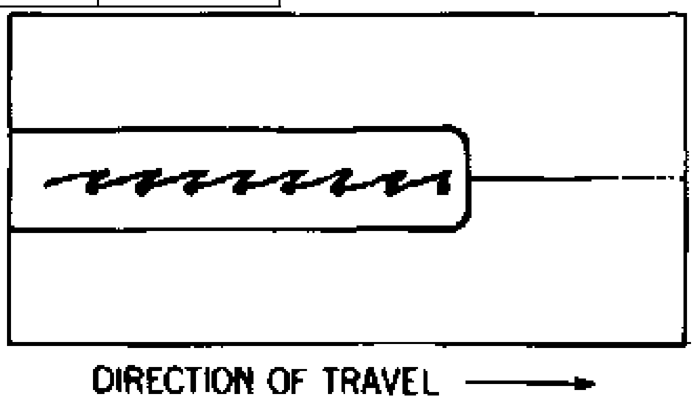
Overview of Welding Positions

5.2 Flat Position

When it is possible, all welding should be done in the position best suited for welding – **the flat position**. And since it is the easiest position to weld in and the most economical, most welding is done in the flat position.

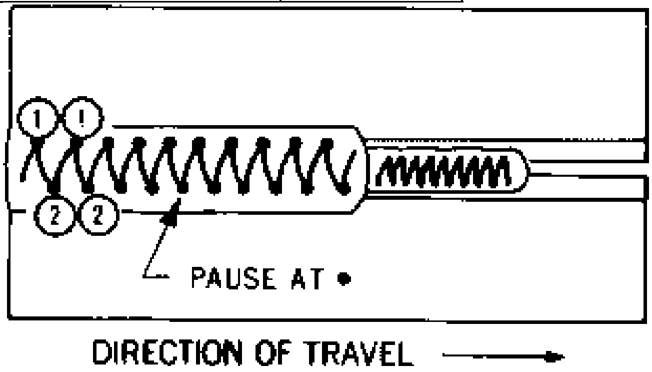
If the weld joint or material to be welded on can be put in the flat position, a welder can often make a better weld. To keep a welder from getting tired, sometimes it will be help resting an elbow on the workbench. Keeping both hands on the welding gun also helps to steady the gun.

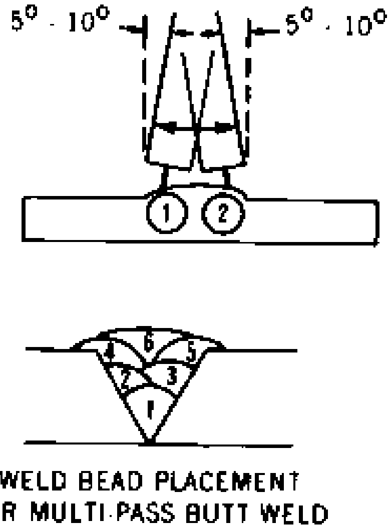
Single Pass Butt Weld	
• Transverse Torch Angle	85 to 90 degrees
• Longitudinal Torch Angle	5 to 10 degrees



Multipass Butt Weld	
• Transverse Torch Angle	

	85 to 90 degrees
• Longitudinal Torch Angle	5 to 10 degrees

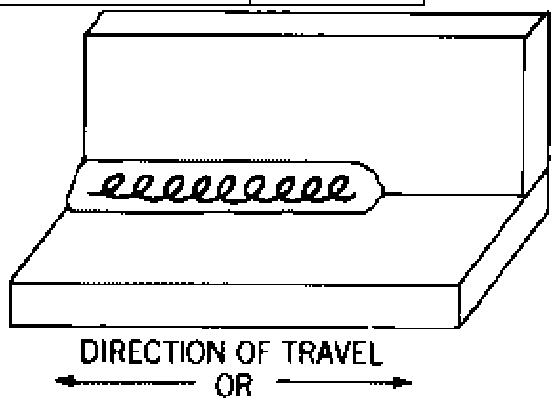


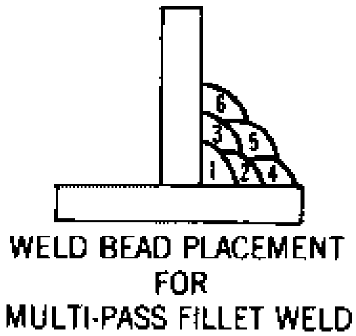


5.3 Horizontal Position

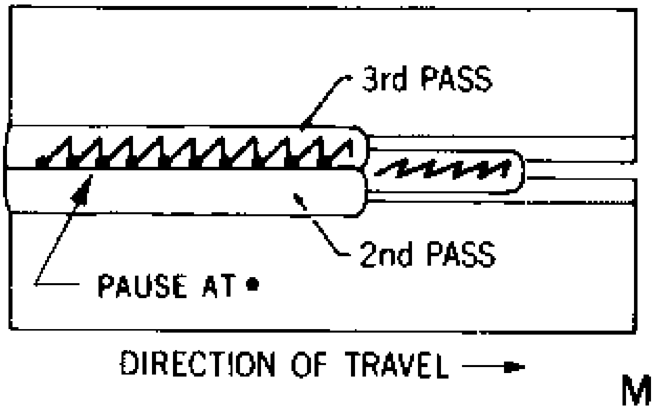
It is important for a welder to always get into a comfortable body position when welding, regardless of the weld position. But as the difficulty of the welding position increases, a comfortable body position becomes even more important. The elbow resting on the bench helps to steady the hands and the welding gun. An experienced welder will always position the body so that it is as easy as possible to reach the workpiece with the welding gun. Also, it is important to position yourself so that good visibility of the arc and weld puddle are available.

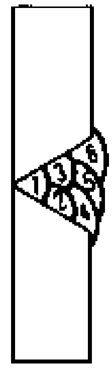
Fillet Weld	
• Transverse Torch Angle	45 degrees
• Longitudinal Torch Angle	5 to 10 degrees





Butt Weld – V–Groove	
• Transverse Torch Angle	85 to 90 degrees
• Longitudinal Torch Angle	5 to 10 degrees
• Single Pass use same weave as 1st pass	





WELD BEAD PLACEMENT FOR **MULTI-PASS BUTT WELD**

5.4 Vertical Position

Vertical welding can be one of the most difficult positions to weld in. This makes preweld setup very important in making high quality welds. A comfortable body position while practicing will help you to **fully concentrate** on your welding. A welder must realize that when out on a job, ideal conditions may not be possible on the job site. In other words, **there is no substitute for practical experience.**

A short circuiting type transfer is helpful for vertical position welds due to its small weld puddle. This can help guard against the puddle "rolling down" or sagging out of the weld puddle area.

Another way to fight the gravity effect on the weld metal is to reduce the voltage and amperage (wire feed speed). These values are lowered about 10% to 15% from settings for the same weld in the flat position.

5.4.1 Vertical Down Welding

It is very important to know when to weld "vertical down" and when to weld "vertical up".

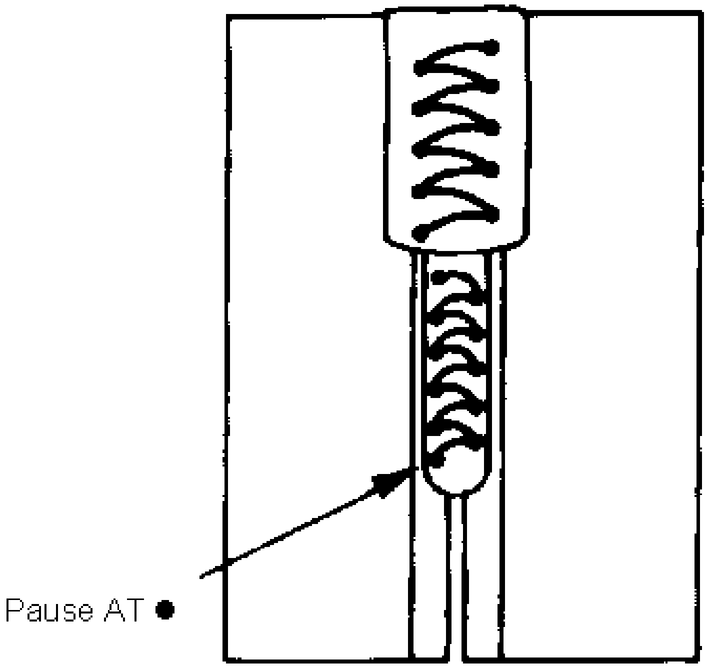
The vertical down technique is often used for welding thin materials. There is usually less penetration welding vertical down than with vertical up. A faster travel speed with vertical down will also lessen penetration. This is very important for thin materials, so as to avoid excessive melt−through. In fact, it is sometimes an advantage to put very thin materials in the vertical position, even if they can be welded in the flat position.

Another application for vertical down welding would be for the root pass on thicker materials, where multi−pass welding is being done. For instance, the root pass on an open root pipe weld is often done with a vertical down technique.

For vertical down welding, the travel angle of the gun is such that a 5−10 degrees drop from the horizontal will help keep the weld puddle from "sagging", or rolling down. Work angles are basically the same as for welds made in the flat position.

It is important to maintain a small molten puddle that holds the deposited weld metal to the base metal. If the molten puddle gets too large, the force of gravity overcomes this surface tension. Thus, the molten weld puddle will run down the plate. This can happen due to improper welder technique, poor fitup, too large of an electrode wire, too high of a voltage and amperage (WFS) or some other problem.

Vertical Down Travel	
• Transverse Torch Angle	85 to 90 degrees
• Longitudinal Angle	5 to 10 degrees
• Single pass welds use same weave technique as first pass shown	
• Use same weave technique for fillet weld	



5.4.2 Vertical Up Welding

For a vertical up weld, the welder begins at the bottom of the weld joint and welds up. Usually, the vertical up technique is used on steel when the joint members are about 1/4" or thicker. In many cases such as on pipe welds, vertical up welds are done once the root pass is in.

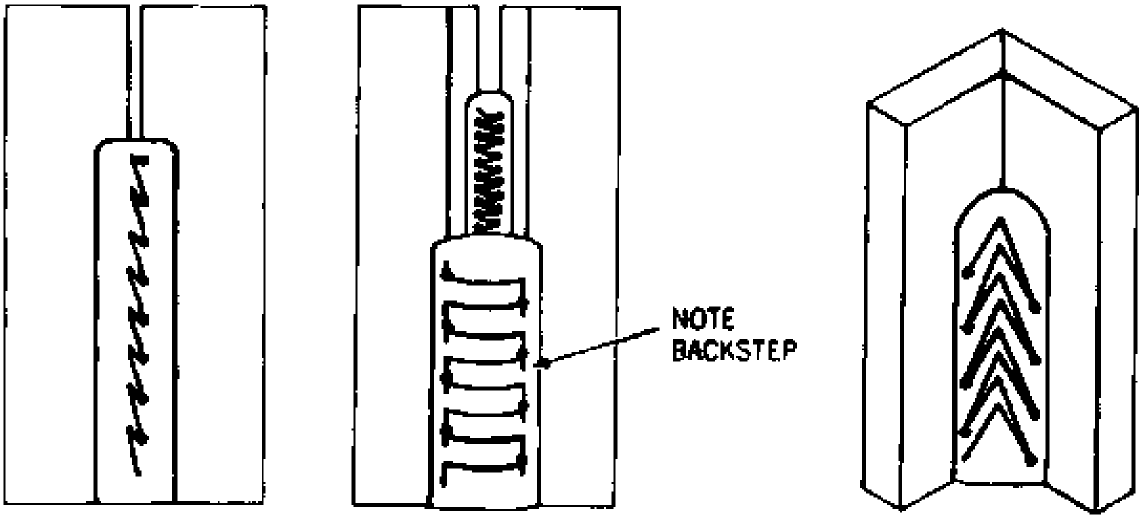
The vertical up technique can be used to provide better penetration and fusion than the vertical down technique.

The main disadvantage of vertical up welding is the possibility of excessive melt−through on thinner metals.

The travel angle of the gun is about a 10−15 degree drop from the horizontal, just as for vertical down welding. Work angles are basically the same as for welds made in the flat position.

A slight weaving motion on a vertical up weld can help control the size, shape and cooling effects of the weld puddle. The type of weave and technique will depend upon such things as joint design, fitup, metal thickness, wire size, etc.

Vertical Up Travel	
• Transverse Angle	85 to 90 degrees
• Longitudinal Angle	10 to 15 degrees



6. WELD DEFECTS

Before describing specifics, it is important to point out the difference between a **weld defect** and a **weld discontinuity**. Every weld can be said to have some discontinuities, since there really is no perfect weld. Some welding instructors, specification books, or codes may allow for a certain amount of discontinuities without calling the weld defective. There is usually a certain point at which the weld will be considered defective. A defective weld would be rejected, for example, for a welder's qualifying test. A defective weld in a manufacturing situation would have to be ground out and replaced, or the entire base metal structure would be rejected.

It is important that some discontinuities in a weld are allowable. When one or more discontinuities cause a weld to fail a particular weld test, this type of discontinuity would then be termed a defect. Acceptable limits can change due to many factors. If the weld requirements are very strict, acceptable limits for the number and size of discontinuities may be quite low.

It is quite easy to encounter many kinds of discontinuities and defects when first learning the GMAW process. Discontinuities and defects can be caused by many factors, including:

- Improper welding techniques
- Improper shielding gas
- Improperly prepared or contaminated base metal
- Dirty or contaminated electrode wire
- Improper secondary circuit
- Equipment problems

The most common weld defects are:

- Lack of Penetration
- Incomplete Fusion
- Porosity
- Undercutting
- Cracking
- Excessive Spatter

Remember: A good weld is not stronger than its weakest point.

6.1 Lack of Penetration

When molten weld metal has not sufficiently penetrated into the base metal, a weld defect can occur, called lack of penetration. Full strength of a joint is not possible if the penetration is not adequate. Lack of penetration can be caused by any one of a number of factors.

Controlled penetration is also difficult to achieve when **poor fit-up** of the base members occurs.

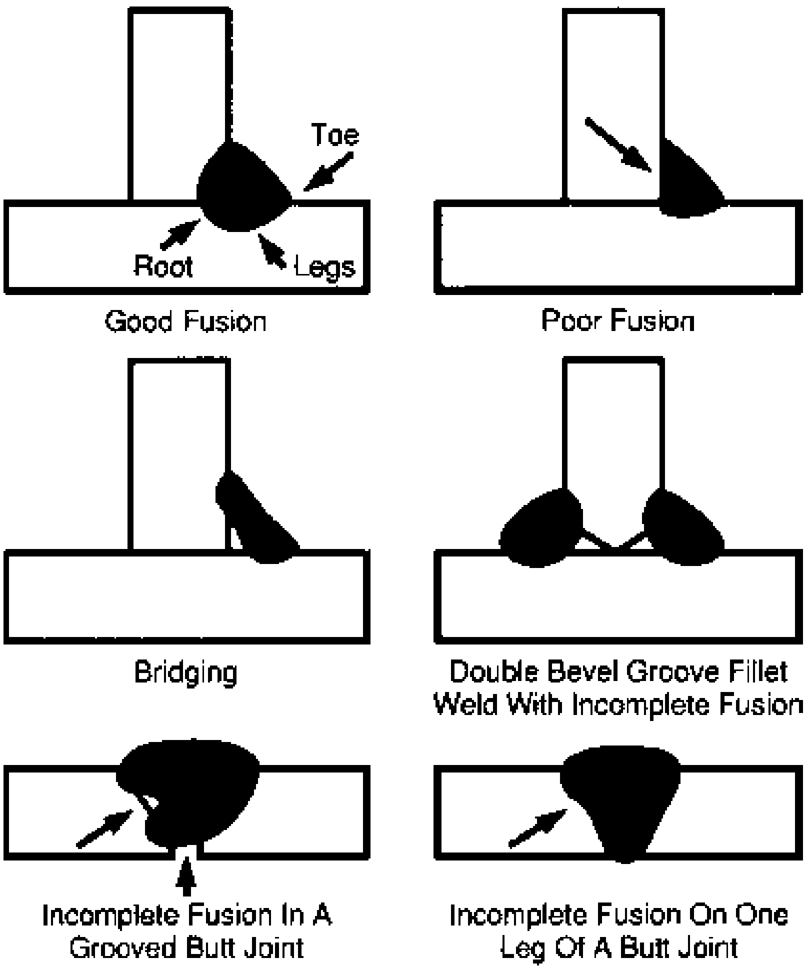
6.2 Incomplete Fusion (Cold Lap)

How well the base metal and weld metal are joined together is termed fusion. Fusion is important if **full strength** of a joint is to be achieved.

Incomplete fusion means that at some point in a weld, the base metal and weld metal have not been joined properly. This could occur at any point in the weld.

Possible causes for incomplete fusion or cold lap:

- Failure to raise the temperature of the weld area to the correct level
- Failure to remove large amounts of mill scale, oxides, or any other foreign materials present on the base metal. These materials could hinder the fusing of the weld metal to the base metal.
- Improper joint design basically refers to the size of the groove angle and root openings on a butt joint. Should these angles or openings be too small for proper electrode extension and gas shielding, incomplete fusion and possible other defects can occur.



6.3 Porosity

Porosity is one of the more common weld defects. It can occur at the surface or face of the weld. Or, porosity can occur inside the weld, where it is difficult to detect. Subsurface porosity cannot be seen with the naked eye but can be detected with various means of testing. Porosity is caused by gases being trapped in the solidifying weld. Put another way, the metal is freezing before the gas has a chance to fully escape from the weld.

Porosity looks like many small holes in a weld – much like the worm holes in a piece of wood. The gas pockets or pores are usually round in shape and can vary in size.

Primary sources for porosity:

• Moisture
• Dirty wire or base metal

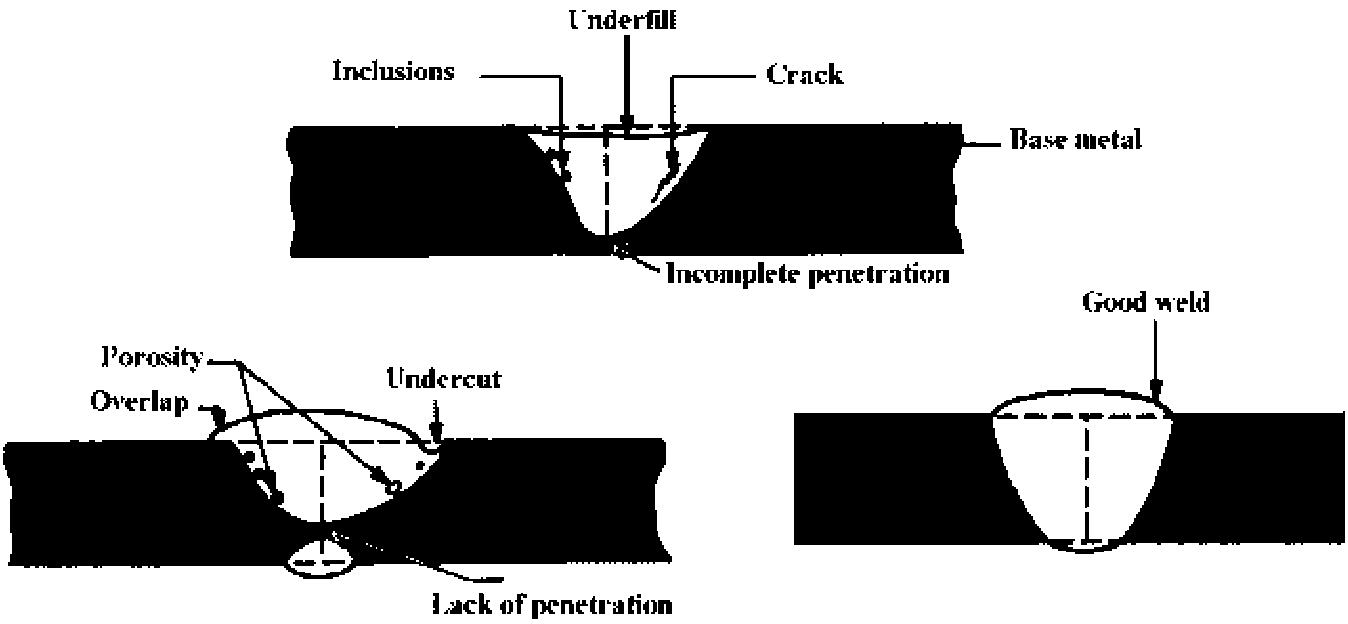
Moisture:

The primary cause of porosity is moisture. This moisture is heated by the welding arc and molten metal, and becomes a gas. Hot metal will absorb some of this gas but the rest of it, being lighter than the metal, floats to the surface and out into the air. The problem comes from the gas that is absorbed by the molten metal.

Hot metal will absorb more gas than cold metal. Therefore, as the weld bead begins to cool, the gas can no longer stay in the cooling metal and must come out. As the metal cools it becomes less liquid, and at some point the escaping gas can no longer float through the hardening metal. The gas is then trapped and causes porosity.

Sources for moisture:

• Contaminated, or wet base metal
• Excessive humidity or any moisture in the air



Dirty wire or base metal:

Electrode wire containing any foreign matter can cause porosity. Because of this, any oils or other foreign materials on or worked into the electrode wire can amount to a substantial amount of material in the resulting weld. Electrode wire should thus be kept as clean as possible. If, for example, a spool of wire mounted on a wire feeder will not be used up in a relatively short time, the wire could cause contaminated welds, especially in a very dirty atmosphere. If this type of situation occurs regularly, spool covers and periodic equipment maintenance can help avoid defects. Just as the electrode wire should be clean, so should the base metal being welded. If the metal has excess oil, scale, rust, etc., porosity could easily result in the weld.

6.4 Undercutting

Undercutting is a defect that appears as a groove in the parent metal directly along the edges of the weld. This type of defect is most commonly caused by improper welding parameters; **particularly the travel speed and arc voltage**.

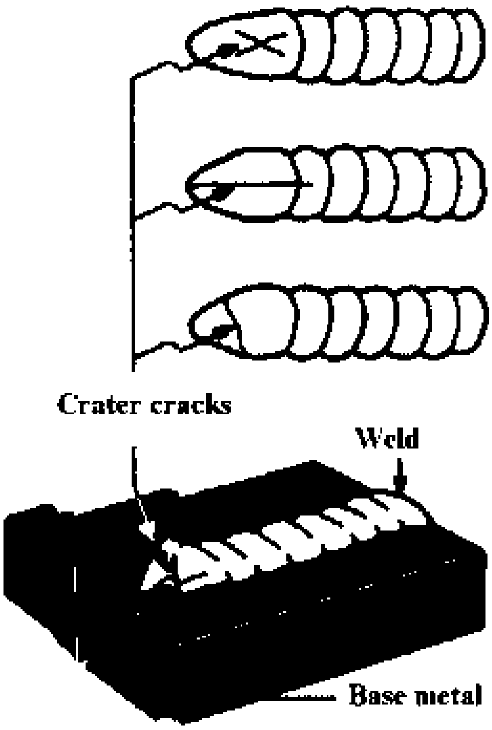
When the travel speed is too high, the weld bead will be very peaked because of its extremely fast solidification. The forces of surface tension have drawn the molten metal along the edges of the weld bead and piled it up along the center. Melted portions of the base plate are affected in the same way. The undercut groove is where melted base material has been drawn into the weld and not allowed to wet back properly because of the rapid solidification. Decreasing the arc travel speed will gradually reduce the size of the undercut and eventually eliminate it. When only small or intermittent undercuts are present, raising the arc voltage or using a leading torch angle are also corrective actions. In both cases, the weld bead will become flatter.

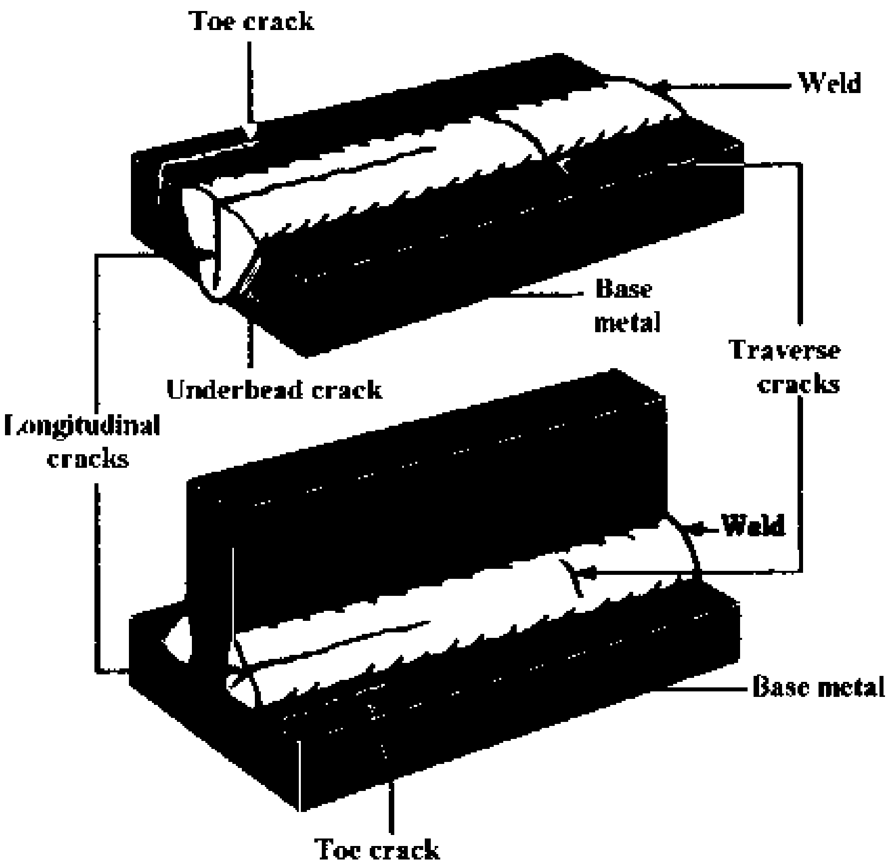
6.5 Cracking

When a metal is put under stress it can crack. Cracks can occur on top of a weld bead, within the weld, or in the base metal.

With the GMAW process and proper welding procedures, weld cracks are held to a minimum. Because GMAW electrode wires have no flux coating to attract moisture, they are by nature low hydrogen in content. They can help avoid cracking in the weld and heat–affected zone if kept clean and dry. Spools or reels must be free of moisture both while being used and when being stored.

A cracking defect is very often associated with the welding of aluminum. A crack can easily occur on aluminum due to metal contraction as the weld pool cools, while the base metal remains hot. This is especially possible in the weld crater at the end of a weld. Therefore, the crater should proper strength and weld size. Cracks may be more numerous with aluminum but they may also occur in stainless steel and steel and galvanized materials. For both stainless steel and steel, cracks may occur if excess heat input is used for the particular thickness of material being welded. Also, steels with high carbon content (over 30 %) are likely to crack due to their hardness.





6.6 Spatter

The need to control spatter when using the GMAW process, obviously depends upon the type of welding being done. For instance, the welding of kitchen chairs or other furniture would be an example where a great deal of spatter would lead to **poor results – and poor sales**! Compare this to a weld on structural steel, where some degree of spatter might be allowed.

Completely spatter–free welds are rare with the GMAW short circuiting method of metal transfer. However, always try to arrive at the parameters which will produce the least amount of spatter possible. Remember – if there is a lot of spatter resulting from a weld, other problems as well could be occurring, possibly causing a weld defect. This is because a particular cause of spatter – low voltage or high wire feed speeds, for example – could also be the cause of a weld defect such as incomplete fusion.

Many electrode manufacturers prepare their electrode wires with various alloys and coatings to help provide less spatter. If the coating is faulty or the wrong electrode is used for the job, much spatter can occur. However, even with the proper electrode, if the welding parameters are not set properly, spatter can occur. Dirt or rust on the electrode wire can also be a cause for excess weld spatter, as well as dirt or rust on the base metal.

- The **shielding gas** selected in a particular situation can have an effect on spatter. CO2 shielding gas is generally considered to yield more spatter for short–circuiting mild steel than a mixture of Argon + CO2, or a mixture of Argon + O2 for Spray arc welding of steel. It is true that CO2 gas is less expensive than the other mixtures, but if spatter is to be reduced, CO2 gas should be avoided for GMAW.

- The gas flow rate, set on the regulator/flowmeter, should also be considered if spatter occurs. Excessive gas flow rates can cause a turbulent, unstable arc which can in turn cause spatter.

- Spatter can also form on the gun nozzle and contact tube, possibly blocking gas flow. As mentioned earlier, certain compounds are available to apply to nozzles so that spatter will not adhere as easily. However, with improper volt–amp (WFS) parameters, spatter can still cause problems and equipment damage.

- Improper voltage and amperage settings can easily cause spatter. Too much voltage when short circuiting, can cause spatter for a certain amperage. This results in the electrode wire not melting properly.

- If a drag or push angle is being used, too much of an angle can lead to spatter. This is because the arc will not be properly directed below the nozzle, as it would be with a proper angle from 5–10 degrees.

- Too much electrode extension (stickout) could cause spatter. With GMAW, too much electrode extension can cause inadequate shielding gas coverage for the weld, as well as improper melting of the electrode due to the longer preheating time for the electrode wire.

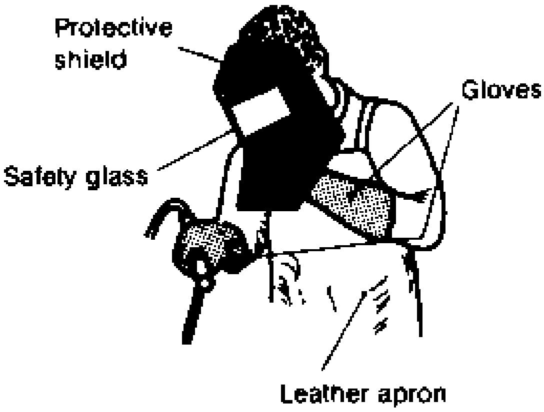
- Too fast of a travel speed can cause spatter because the molten metal deposited is not given enough time to properly wet out.

7. SAFETY AND PRECAUTION

As in any welding process, Gas Metal Arc Welding (GMAW) safety precautions are very important. All information relating to the safe operation of the welding equipment and the welding process **must be fully understood** before attempting to begin work. A careless welder who does not observe some simple rules can cause a dangerous situation for everyone in the area. The process of arc welding creates several hazards which must be guarded against. Useful safety information can be found in the **Owner's Manual** that comes with each item of welding equipment.

GMAW is an electrical welding process. Therefore, electrical energy is required from a welding machine. If the welding machine has the characteristics of a transformer or a motor−generator design, electrical energy is required as primary power to operate it. The welding machine must be installed according to the manufacturer's recommendation and in accordance with the National Electrical Code and local code requirements.

7.1 Personal Safety Equipment (Obligatory)



Personal Safety Equipment (Obligatory)

7.2 Electrical Shock

Welders must be concerned about the possibility of electrical shock. It should be remembered that electricity will always take the path of **least resistance**. If there is a proper secondary circuit, the current will follow that path. However, if there are poor connections, bare spots on cables, **or wet conditions**, the possibility of electrical shock does exist.

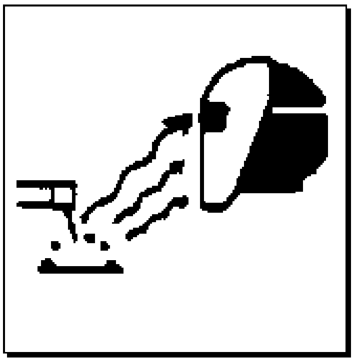
A welder should never weld while standing in water. If wet working conditions exist, certain measures should be taken. Such measures include standing on a dry board or a dry rubber mat when welding. Likewise, the welding equipment should not be placed in water. In addition, gloves and shoes must be kept dry. Even a person's perspiration can lower the body's resistance to electrical shock.

Important Rules:

- Do not touch live electrical parts
- Wear dry, hole−free insulating gloves and body protection
- Insulate yourself from work and ground using dry insulating mats or covers
- Disconnect input power or stop engine before installing or servicing this equipment
- Properly install and ground the equipment including the welding table
- When making input connections, attach proper grounding conductor first
- Turn off all equipment when not in use
- Do not use worn, damaged, undersized, or poorly spliced cables
- Do not touch electrode if in contact with the work or ground

• Use only well maintained equipment. Repair or replace damaged parts at once
• Keep all panels and covers securely in place

7.3 Arc Rays



Several possible hazards exist due to the electric arc, infrared and ultraviolet rays. The light and rays can produce a burn similar to sunburn, The arc rays, however, are more stronger than sunburn since the welder is so close to the source. Any exposed skin can be quickly burned by these rays.

Rules:

- Keep your head out of the fumes. Do not breathe the fumes.
- If inside, ventilate the area and/or use exhaust at the arc to remove welding fumes and gases

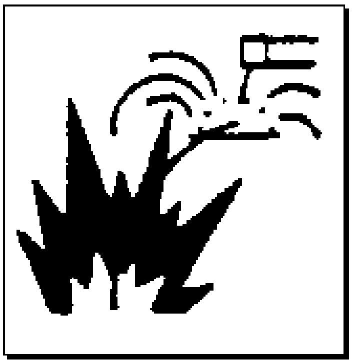
7.4 Fumes and Gases

Fumes and gases can be hazardous to your health.

Rules:

- Wear a welding helmet fitted with a proper shade of filter to protect your face and eyes when welding or watching.
- Use protective screens or barriers to protect others from flash and glare; warn others not to watch the arc
- Wear approved safety glasses. Side shields recommended.

7.5 Fire or Explosion

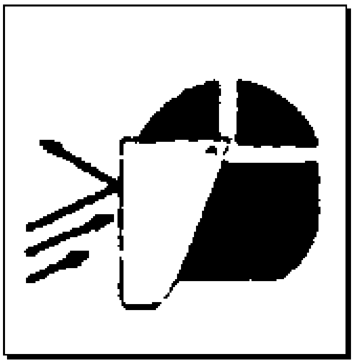


Welding can cause fire or explosion

Rules:

- Protect yourself and others from flying sparks and hot metal
- Do not weld where flying sparks can strike flammable material
- Remove all flammables near of the welding arc
- A fire extinguisher should all the time available

7.6 Flying Sparks



Flying sparks and hot metal can cause injury.

Rules:

- Chipping and grinding cause flying metal. Remove slag after welds cool down

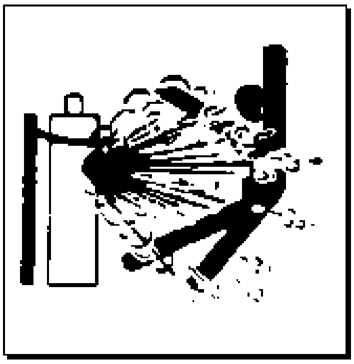
- Wear approved face shield or safety goggles. Side shields recommended

- Wear protective clothing such as heat resistant jackets, aprons etc. Thin cotton clothing is inadequate protection

- Wear clean clothes. Do not wear clothing that has been stained with oil and grease. It may burn if ignited by the heat of the arc

- To protect the feet, high top leather shoes are recommended

7.7 Gas Cylinders



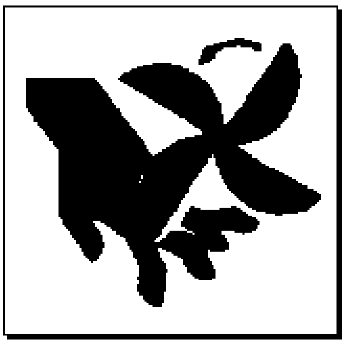
Regardless of the content, pressurized cylinders must at all times be handled with great care. Shielding gases such as carbon dioxide, argon and helium are nonflammable and nonexplosive. But for instant a broken off valve, however, will release extremely high pressures, which could cause the cylinder to be hurled about at dangerously high speeds. Another way of thinking about this pressure is to compare a cylinder to a balloon. If a balloon is blown up and then released, the jet force of air escaping causes the balloon to fly about quite rapidly. The same would be true if a cylinder valve would break off. Only now, the weight of the cylinder and the extremely high pressure could easily cause a very damaging and possibly fatal accident. Cylinders should be securely fastened at all times. Chains are usually used to secure a cylinder to a wall or cylinder cart. When moving or storing a cylinder, a threaded protector cap must be fastened to the top of the cylinder. This protects the valve system should it be bumped or the cylinder dropped. It is accepted procedure to roll a cylinder in the upright position when moving the cylinder.

It is also very important to keep excess heat of any kind away from cylinders. When a cylinder is exposed to too much heat, the pressure inside the cylinder will increase.

Rules:

- Keep cylinders away from any welding or other electrical circuits
- Never allow a welding electrode to touch any cylinder
- Install and secure cylinders in an upright position by chaining them to a stationary support or equipment cylinder rack to prevent falling or tipping

7.8 Moving Parts

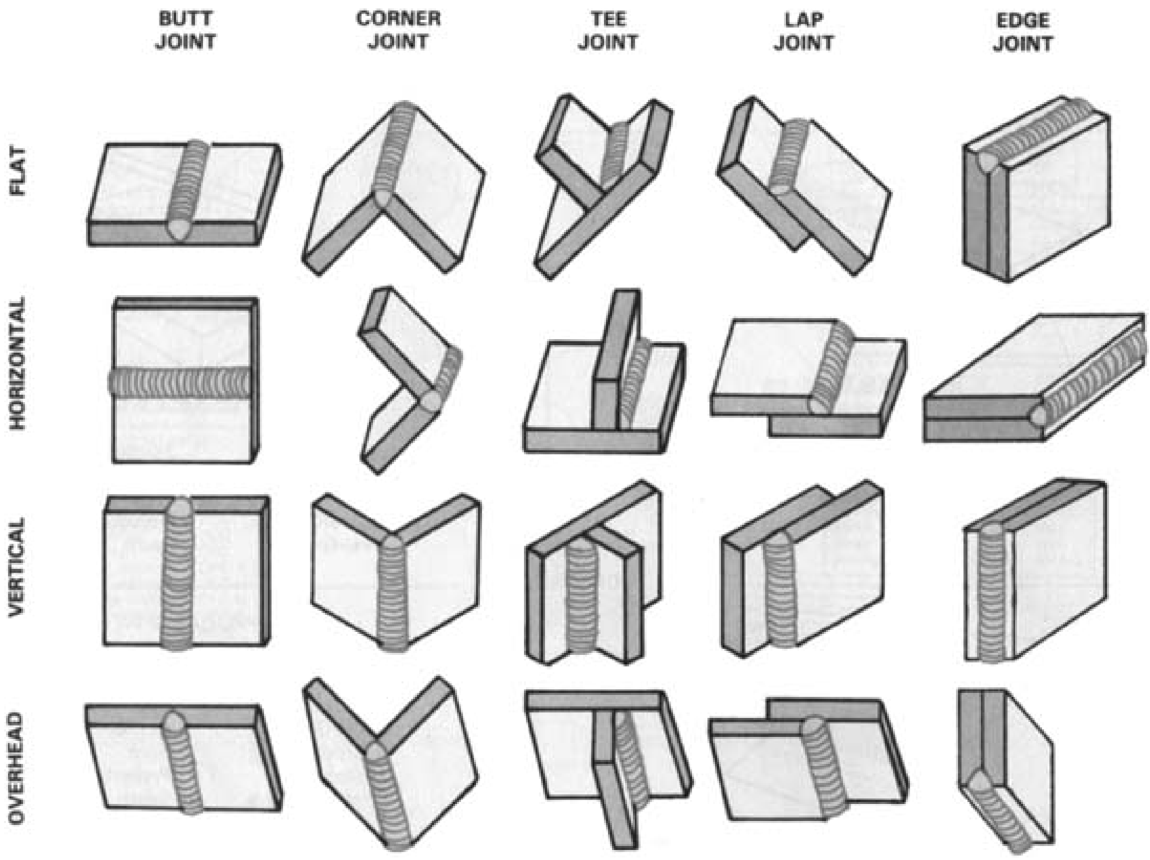


Moving parts can cause injury.

Rules:

- Keep yourself away from pinch points such as drive rolls
- Keep all doors, panels, covers, and guards of the welding machine closed and securely in place

APPENDIX NO. 1 TYPES OF JOINTS AND WELDING POSITIONS



Types of Joints and Welding Positions

APPENDIX NO. 2 TROUBLESHOOTING

Fault or Defect	Cause and/or Corrective Action
Porosity	• Oil, heavy rust, scale, etc. on plate • Shielding problem: wind, gas cylinder valve off, gas hose leaks, gun or/and cables leaking gas, freezing of CO2 regulator/flowmeter • Improper gun angle • Too much wire feed speed (amperage), or voltage too high • Welding travel speed too fast • Nozzle to work distance too great • Failure to remove glass (kind of slag or oxide) between weld passes • Welding over slag from covered electrode
Lack of penetration	• Weld joint to narrow • Welding current too low; to much electrode stickout • Weld puddle rolling in front of the arc
Lack of fusion	• Welding voltage and/or current too low • Travel speed to low • Welding over convex bead • Torch oscillation too wide or too narrow • Excessive oxide on plate
Undercutting	• Travel speed too high • Welding voltage too high • Excessive welding current • Insufficient dwell time at edge of weld bead
Cracking	

	• Incorrect wire chemistry • Weld beat too small • Poor quality of material being welded • To much moisture • Excessive heat
Unstable arc	• Check gas shielding • Check wire feed system
Poor weld starts or wire stubbing	• Welding voltage too low • Wire extension too long • Poor work connection • Clean glass (kind of slag or oxide) from plate
Excessive spatter	• Use Ar–CO2 or Ar–O2 instead of poor CO2 • Too high of a gas flow • Too much voltage
Burn through	• Welding current too high • Travel speed too slow • Decrease width of root opening • Use Ar–CO2 or Ar–O2 instead of poor CO2
Convex bead	• Welding voltage and/or current too low • Excessive electrode extension • Weld joint too narrow

COST CALCULATION FOR GMAW WELDING (ONE WEEK TRAINING COURSE) – COSTS PER TRAINEE

Expenses	**Current Prize**	**Qantity & Cost per Trainee**	
Consumables		**Qty.**	**Cost**
Exercises # 1 Flat bar 1/8x1/2x6mts.	108.00	360 mm 2 pcs. 180 mm	6.50
Exercise # 2 & # 3 Flat bar 3/16x1 1/4x6mts.	232.00	1,440 mm 8 pcs. 180 mm	56.00
Exercise # 4 & # 5 Flat bar 3/8x1 1/2x6mts.	232.00	1,800 mm 10 pcs. 180 mm	70.00
Exercise # 6 & # 7 Flat bar 3/8x1 1/2x6mts	232.00	1,440 mm 8 pcs. 180 mm	68.00
Mig/Mag wire 0.8 mm	800.00	¼ Spool	200.00
Carbon dioxide CO2	600.00	¼ Content	150.00
Grinding disc 4”	35.00	½ pc.	17.50
Chop Saw disc 14”	180.00	1/8 pc.	22.50
			590.50
Safety Equipment			
Dark glass	15.00	1/3 pc.	5.00
Clear glass	10.00	1/3 pc.	3.50

Hand gloves	100.00	1/5 pair	20.00
Goggles	35.00	1/5 pc.	7.00
			35.50
Handouts			
Band paper A4	1.00	45 pcs.	45.00
Photo copying	1.00	45 pcs.	45.00
Fastener	.50	1pc.	0.50
Folder	3.00	1 pc.	3.00
			93.50
Administrative			
Certificates	5.00	1 pc.	10.00
Evaluation sheet	1.00	1 pc.	1.00
Participant evaluation form	1.00	1 pc.	1.00
Participant reaction sheet	1.00	1 pc.	1.00
Resume	1.00	1 pc.	1.00
Printer Cartridge	1,200.00	2/250	10.00
			24.00
Maintenance & Depriciation			
GMAW machine	200 each seminar	¼	50.00
Portable grinder	80 each seminar	¼	20.00
Chop Saw	100 each seminar	¼	25.00
			95.00
Energy Consumption			
GMAW machine	estimated		125.00
Portable grinder	estimated		10.00
Aircon	estimated		125.00
TV	estimated		2.50
Projector	estimated		10.00
Lights	estimated		20.00
			292.50
Total Cost			**1,131.00**

LIST OF NEEDED RESSOURCES FOR "MIG/MAG WELDING" COURSE

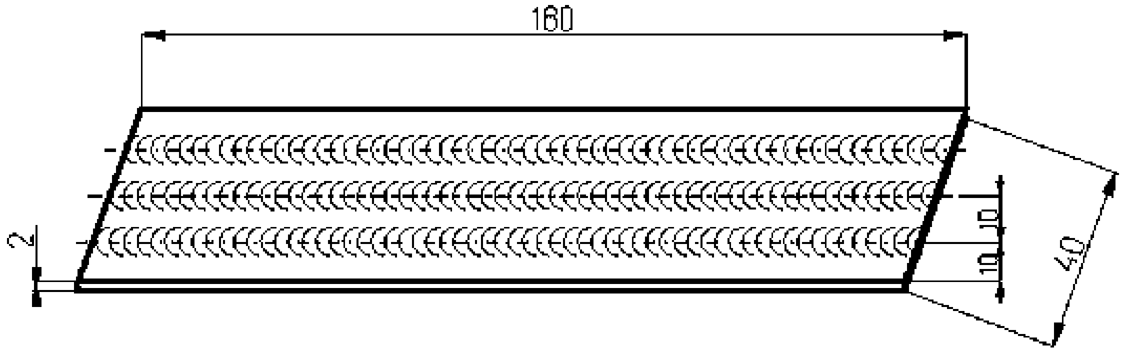
					Need to Order/Replace/Organize

Resource	Checked	Unit	Qty for 1 Trainee	Qty for 4 Trainees	Unit	Qty	Unit Price	Amount
Teaching Aids								
Overhead Projector								
Overhead Foils								
Video Tapes								
T.V−VHS								
White Baord								
White Board Marker								
Forms								
Certificates								
Evaluation Sheet								
Participant Evaluation Form								
Participant reaction Sheet								
Resume								
Consumables and Parts for Exercises								
Metals								
Flat bar 1/8x11/2x6mts.								
Flat bar 3/16x11/4x6mts								
Flat bar 3/16x11/4x6mts								
Flat bar 3/8x11/2x6mts								
Flat bar 3/8x11/2x6mts								
Flat bar 3/8x11/2x6mts								
Flat bar 3/8x11/2x6mts								
Gas								
Carbon Dioxide CO2								
Wire								
Mig/Mag Wire 0.8mm								
Safety Equipment & Accessories								
Dark Glass								
Clear Glass								
Hand Gloves								
Goggles								
Apron								

Handshield								
Helmet								
Chipping Hammer								
Wire Feeder “V” Groove 0.8mm								
Nozzle								
Contact Tube								
Contact tube Holder								
Gas Diffusor								
Swan Neck 50 deg.								
Cable Support								
Dip Nozzle								
Grinding disc. 4”dia.								
Cutting disc.14” dia.								

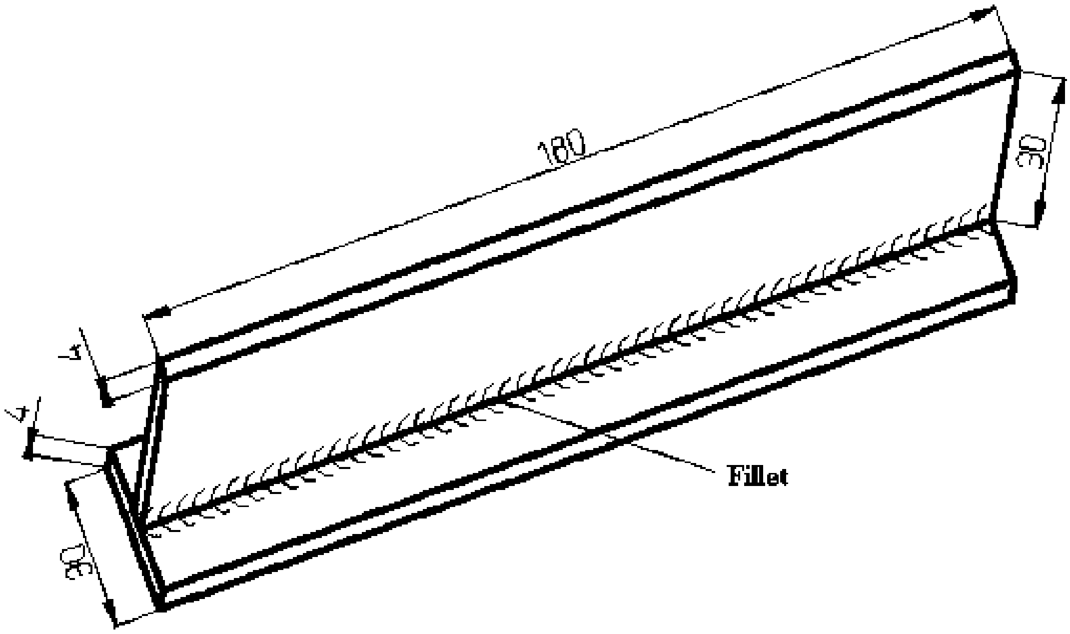
PRACTICAL EXERCISES

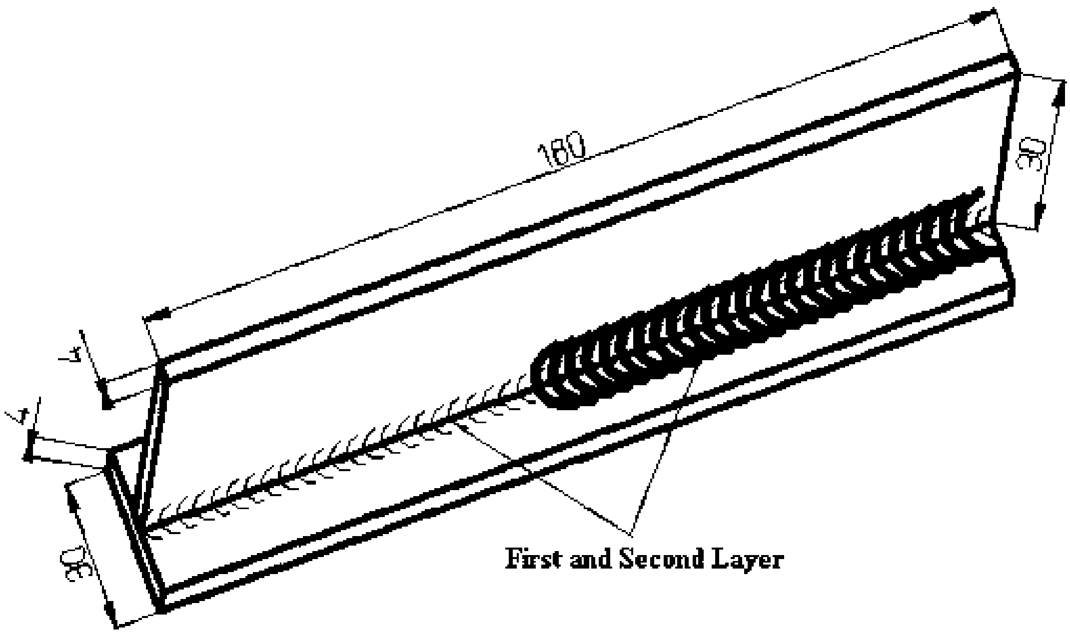
EXERCISE NO. 1
Deposit continous bead
Flat position from right to left
5 Pieces Flatbar 1/8 × 1 1/2 each Trainee



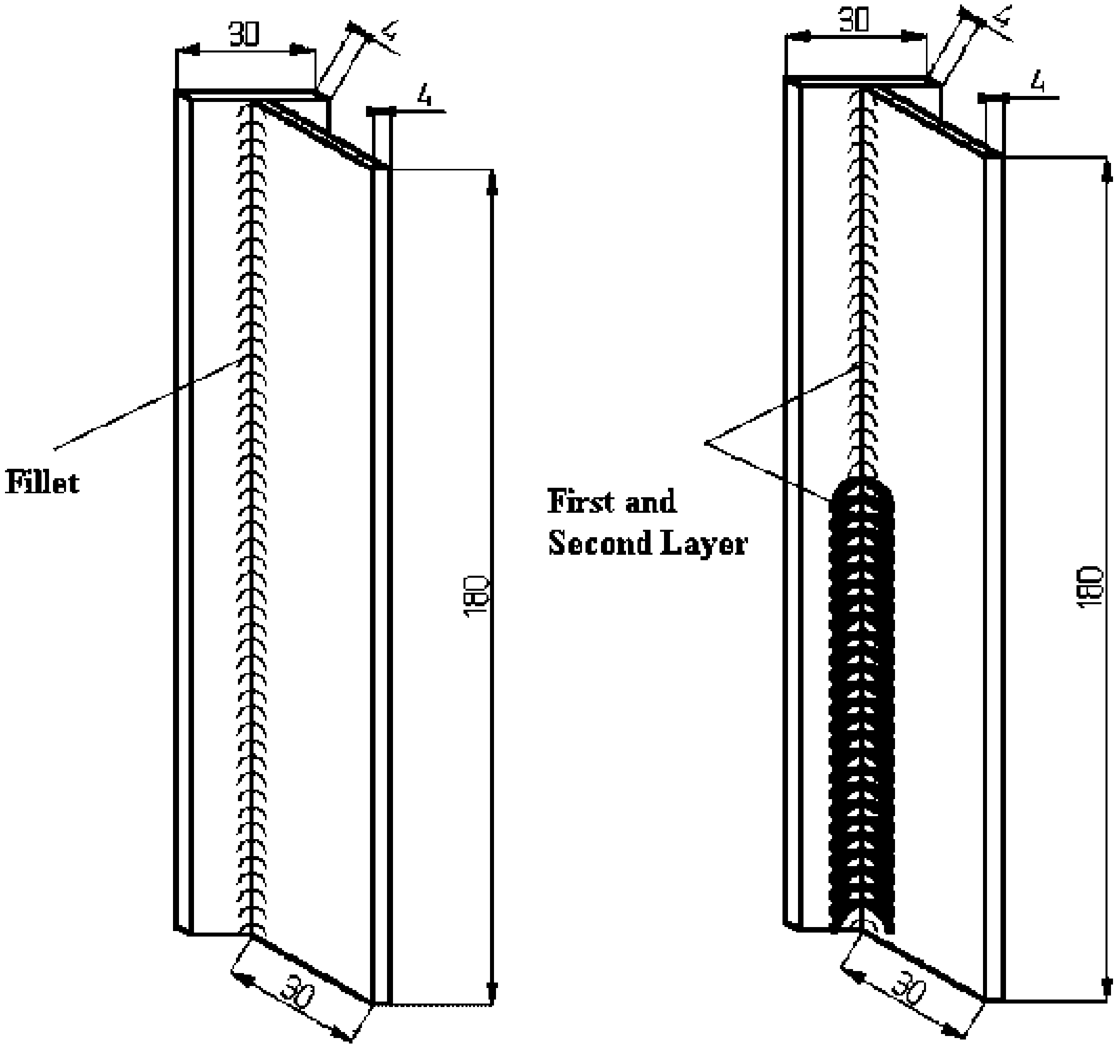
Please mark the steel plate with 3 lines with 10 mm clearance

EXERCISE NO. 2
Single and Double Pass T–Joint both sides
Horizontal position from right to left
10 Pieces Flatbar 3/16 × 1 1/4 each Trainee

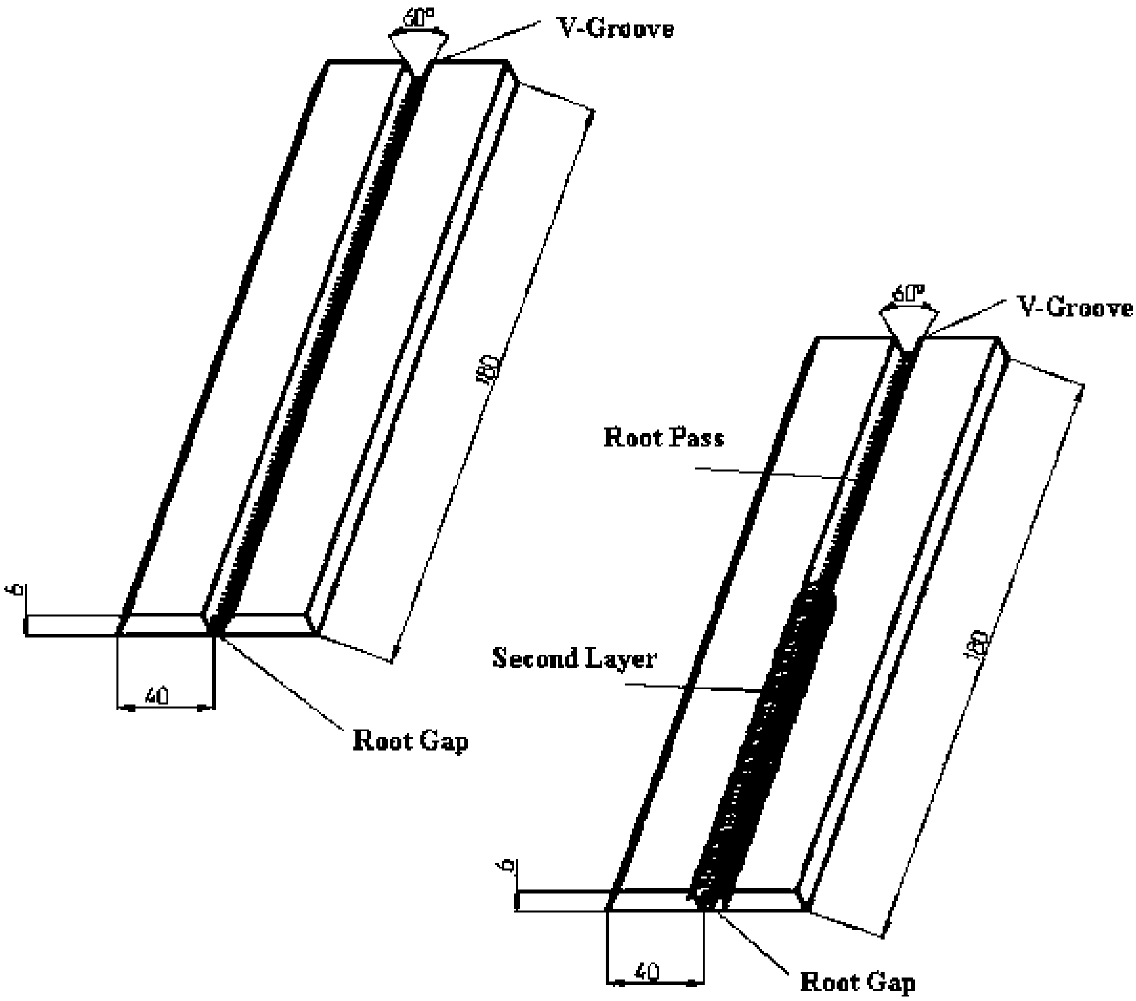




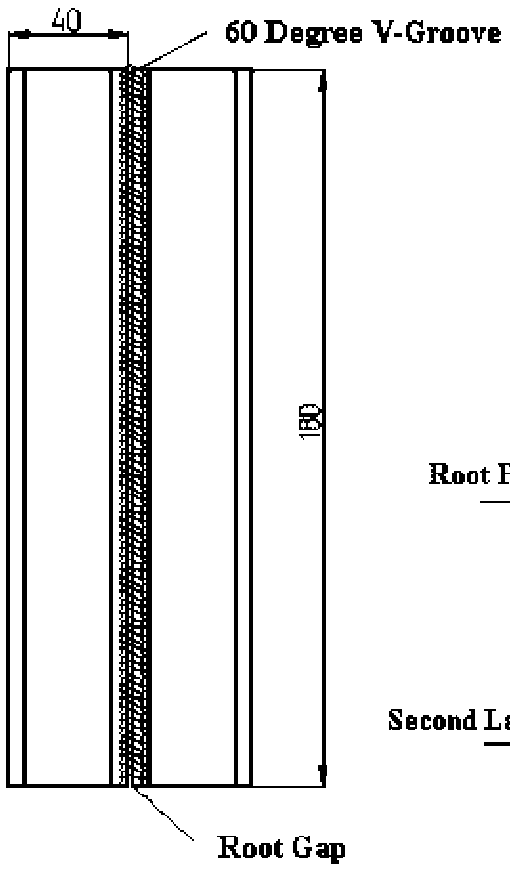
EXERCISE NO. 3
Single and Double Pass T–Joint both sides
Vertical position from bottom to top
10 Pieces Flatbar 3/16 × 1 1/4 each Trainee

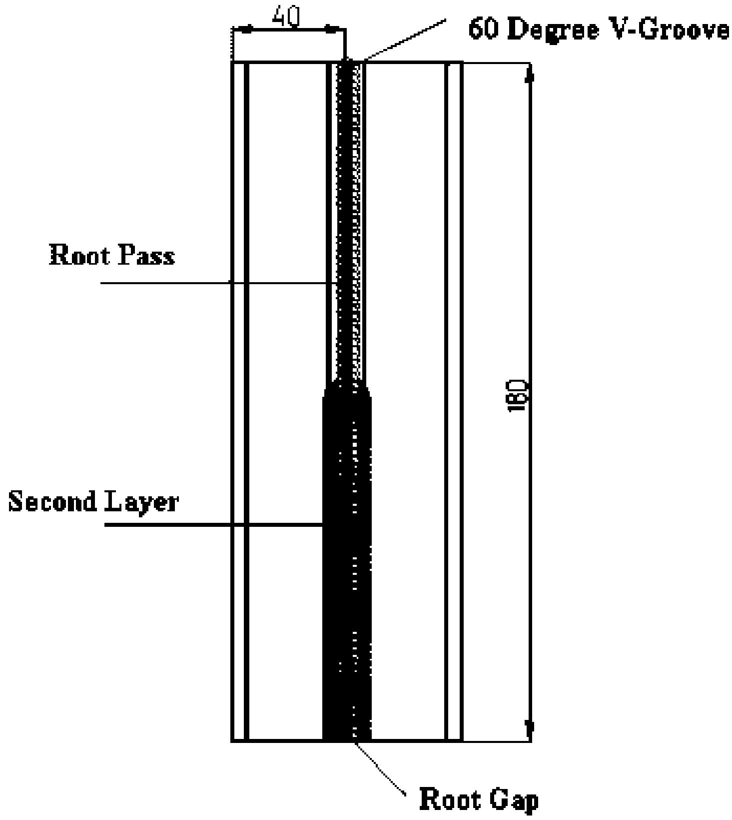


EXERCISE NO. 4
Single and Double Pass Butt-Joint with 60° V-Groove
Root Gap 1,5 mm
Flat position from right to left
6 Pieces Flatbar 3/8 × 1 1/2 each Trainee

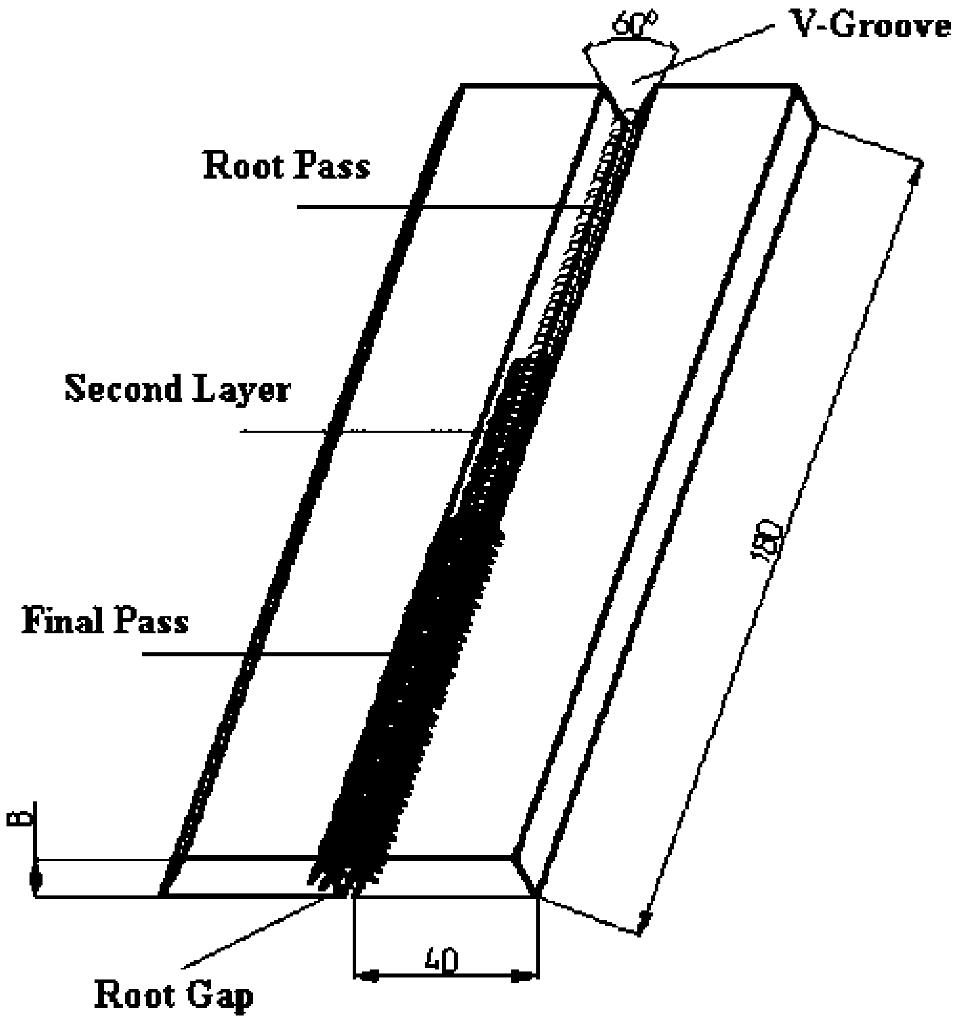


EXERCISE NO. 5
Single and Double Pass Butt–Joint with 60° V–Groove
Root Gap 1,5 mm
Vertical position from bottom to top
6 Pieces Flatbar 3/8 × 1 1/2 each Trainee

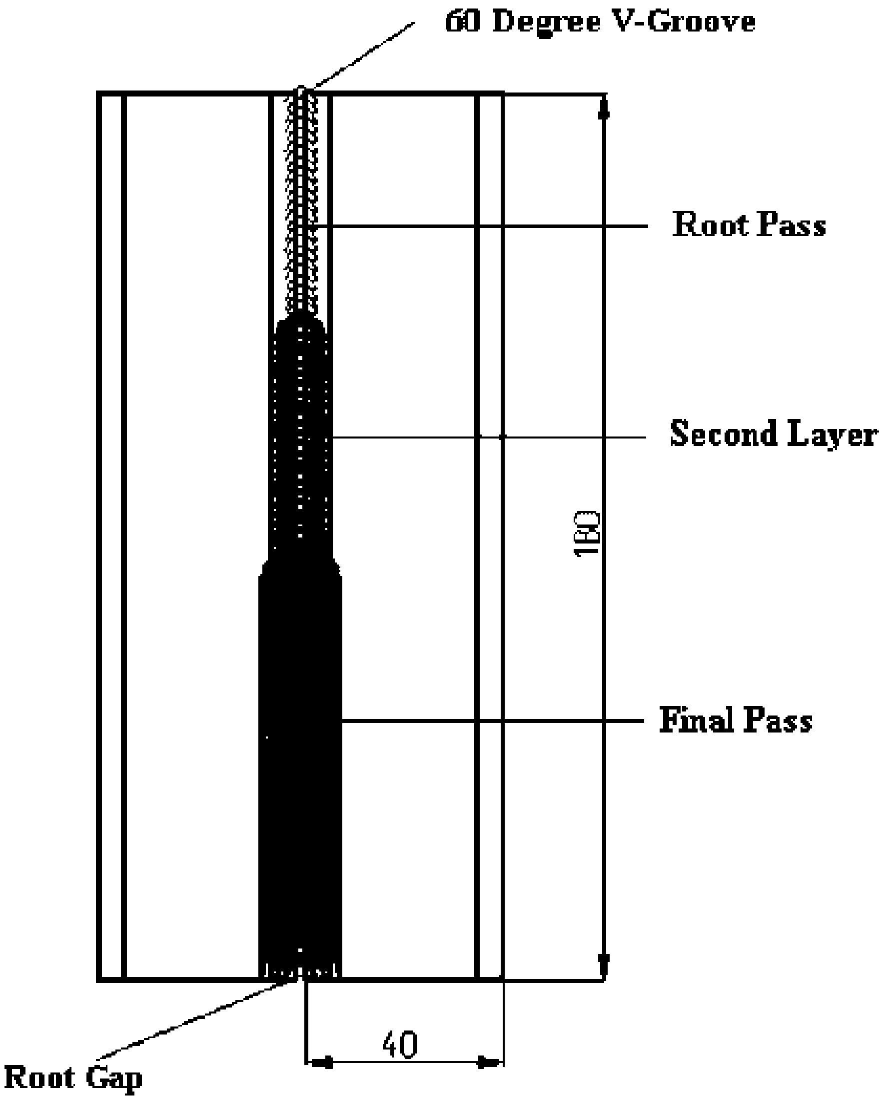




EXERCISE NO. 6
Multiple Pass Butt–Joint with 60° V–Groove
Root Gap 1,5 mm
Flat position from right to left
4 Pieces Flatbar 3/8 × 1 1/2 each Trainee



EXERCISE NO. 7
Multiple Pass Butt–Joint with 60° V–Groove
Root Gap 1,5 mm
Vertical position from bottom to top
4 Pieces Flatbar 3/8 × 1 1/2 each Trainee

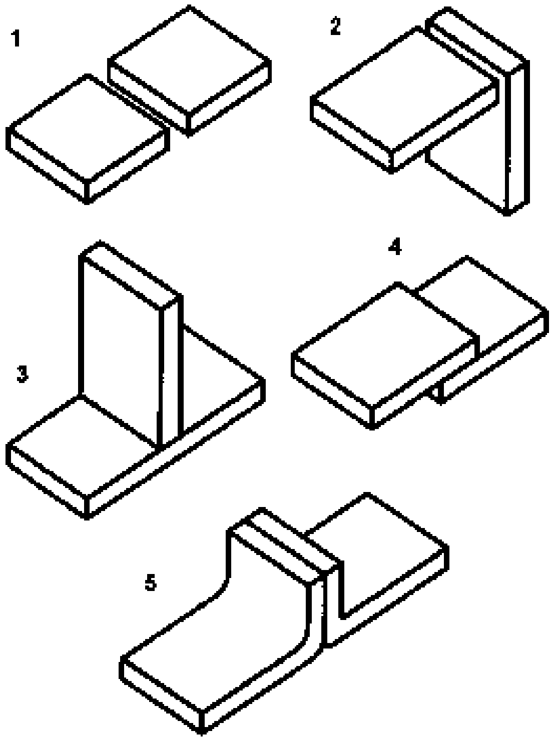


PREVIOUS KNOWLEDGE TEST

1. What is the function of the coating on an SMAW electrode?

a.	The coating forms a gas envelope which protects the molten material from nitrogen and oxygen	☐
b.	The coating slag absorbs impurities from the welding puddle	☐
c.	The coating forms slag above the welding bead which reduces stresses in the material through a slower cool down process	☐
d.	The coating is necessary to burn an arc	☐
e.	The coating is important to weld workpieces, which are very rusty or covered with oil, paint or grease.	☐

2. The picture besides shows common joint designs. Put the correct number in the table below.



No.	Joint Design
	Edge joint
	Corner joint
	Butt joint
	T joint
	Lap joint

3. Please name five basic hazards in SMAW welding:

a	
b	
c	
d	
e	

4. Which parameter is adjustable at the SMAW–welding machine?

a. Voltage ☐ b. Ampere ☐ c. Watt ☐